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TARGET SEEKER SIMULATOR DEVELOPED FOR FIVE-INCH ASMD MISSILE FL--ETC(U)
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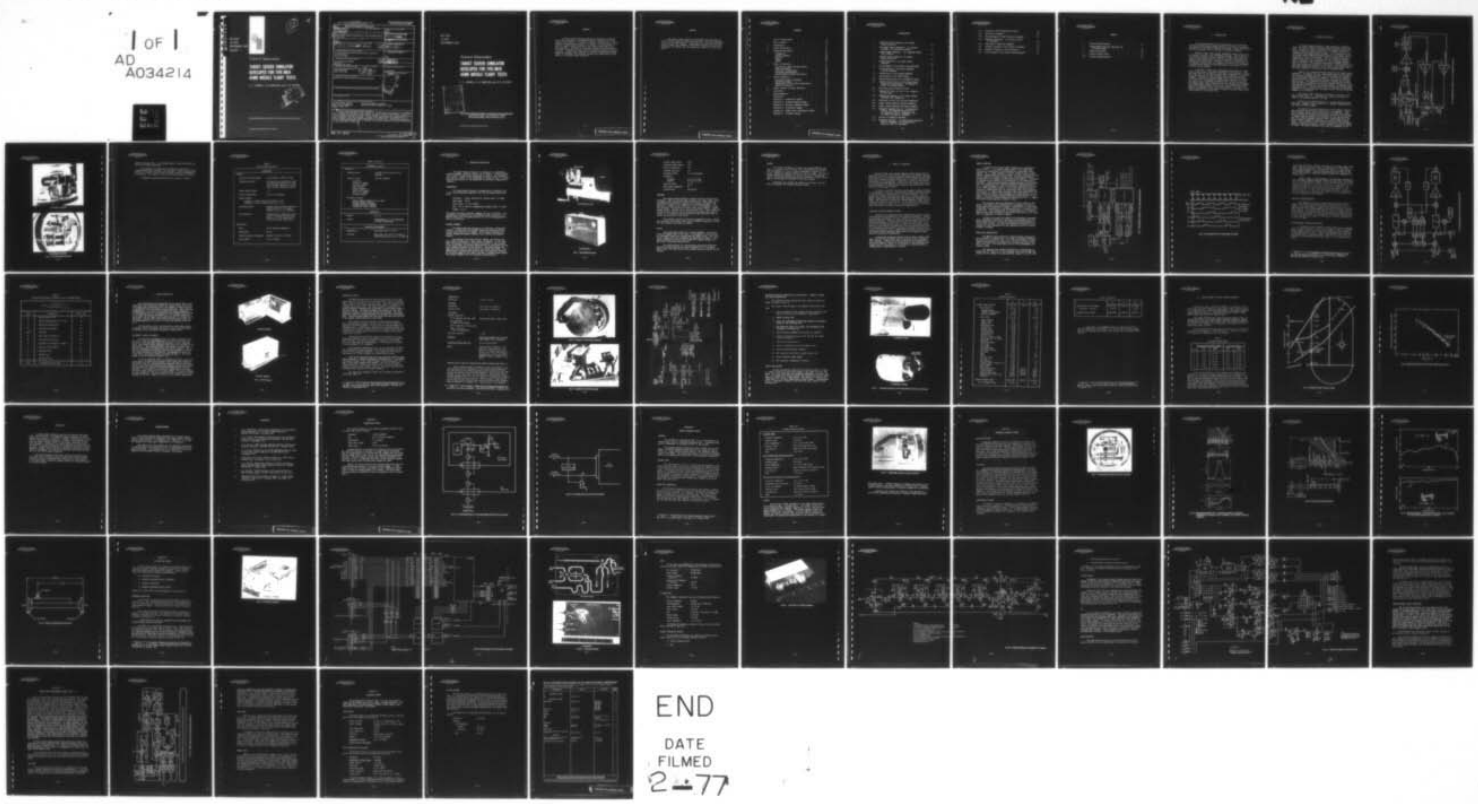

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Technical Memorandum

TARGET SEEKER SIMULATOR DEVELOPED FOR FIVE-INCH ASMD MISSILE FLIGHT TESTS

E. C. JARRELL, D. R. MARLOW, and H. B. TETENS

THE JOHNS HOPKINS UNIVERSITY ■ APPLIED PHYSICS LABORATORY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A target seeker simulator has been successfully developed that, when installed in an AN/BQM-34A drone, simulates an active homing cruise missile. In order to simulate realistically a cruise missile illuminating and homing on a target, it was necessary to keep the seeker antenna pointed at the target regardless of the drone movement. Pointing of the seeker antenna is accomplished on the basis of signals received from an associated beacon at the target site. Flight tests conducted at the White Sands Missile Range (WSMR) in September 1975 produced satisfactory operational performance by the target seeker simulator.

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Operating under Contract N00017-72-C-4401 with the Department of the Navy

ABSTRACT

A target seeker simulator has been successfully developed that, when installed in an AN/BQM-34A drone, simulates an active homing cruise missile. In order to simulate realistically a cruise missile illuminating and homing on a target, it was necessary to keep the seeker antenna pointed at the target regardless of the drone movement. Pointing of the seeker antenna is accomplished on the basis of signals received from an associated beacon at the target site. Flight tests conducted at the White Sands Missile Range (WSMR) in September 1975 produced satisfactory operational performance by the target seeker simulator.

PREFACE

The target seeker simulator development was undertaken because the Navy target inventory did not have a realistic simulation of an active cruise missile, a requirement for the five-inch ASMD missile flight test program. This report documents the system engineering, the design, and the flight-test results for that simulator.

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1. INTRODUCTION

The validation phase in the development of the five-inch Antiship Missile Defense (ASMD) missile is currently in progress. The missile is dual-mode RF ARM and IR homing. The RF ARM provides midcourse guidance, and IR provides the terminal guidance.

Missile flight tests against AN/BQM-34A target drones will be conducted as part of the validation program. The RF portion of the missile guidance system is designed to home on RF radiation from an enemy antiship missile that is actively illuminating and homing on the firing ship. Therefore, testing the RF portion of the missile requires that the target drone carry an RF transmitter to simulate the radiation characteristics of the seeker for the antiship cruise missile.

A realistic flight test necessitates simulating the transmitted power (P_tG_t) of the enemy antiship cruise missiles. Physical limitations of the BQM-34A drone make it impossible to simulate fully the P_tG_t product that antiship cruise missiles typically transmit. However, by making maximum use of the space available in the drone and designing the target seeker simulator to track the launch site, an adequate simulation of the P_tG_t is obtained. A tracking target seeker simulator has been successfully developed that continuously directs an RF beam at the missile launch site during the incoming flight of the target drone. Pointing of the beam is accomplished on the basis of signals received from an associated beacon at the launch site.

2. SYSTEM DESCRIPTION

The target seeker simulator, when installed in a BQM-34A drone, is used to simulate an active homing antiship cruise missile. The drone is radio controlled from a ground station to fly inbound toward the missile launch site. In order to provide a realistic active-seeker signal strength, it is necessary to keep the target-seeker-simulator antenna pointed at the launch site irrespective of the drone movement. This is achieved by having a ground-based beacon at the launch site and a tracking receiver with a steerable antenna operating in a dual (transmit/receive) mode in the drone. The receiver activates the antenna gimbals to keep the antenna beam centered on the beacon. In this way the target seeker simulator appears to be an active homing seeker while the drone trajectory can deviate from an incoming course.

Figure 1 is a simplified block diagram of the target seeker simulator. The signal from the ground-based beacon is received by the four-port monopulse antenna. The four signals are processed by the monopulse comparator to produce Σ, ΔAz, and ΔEl signals, which are routed to the receiver through a diplexer and two bandpass filters. The transmitter frequency is sufficiently removed from the beacon frequency to allow the diplexer and filters to provide adequate isolation for the receiver inputs. Adjustable phase shifters in the Σ and ΔEl lines allow the receiver and microwave subsystem to be phase matched, providing correct sum and difference signals to the receiver.

The target seeker simulator is located in the nose of the BQM-34A drone (Fig. 2). A hemispherical radome is provided in place of the standard BQM-34A nose cone.

Control of the seeker simulator is via the BQM-34A RF command link. Separate input controls are: STANDBY, TRANSMITTER ON, and CAGE and UNCAGE command.

The system is placed automatically in the standby condition when the drone +28 VDC special-devices bus is energized. A special prelaunch signal places the antenna in the cage mode during launch, fixing the antenna pointing angle relative to the aircraft. In normal pretrack operation the system is in the caged position with the interim expendable emitter (IEE) transmitting until the beacon signal strength is sufficient to provide reliable system track. At this time the drone controller receives a beacon-signal-present indication and gives an uncage command, placing the system in track. The seeker simulator has a pull-in capability of ±6°

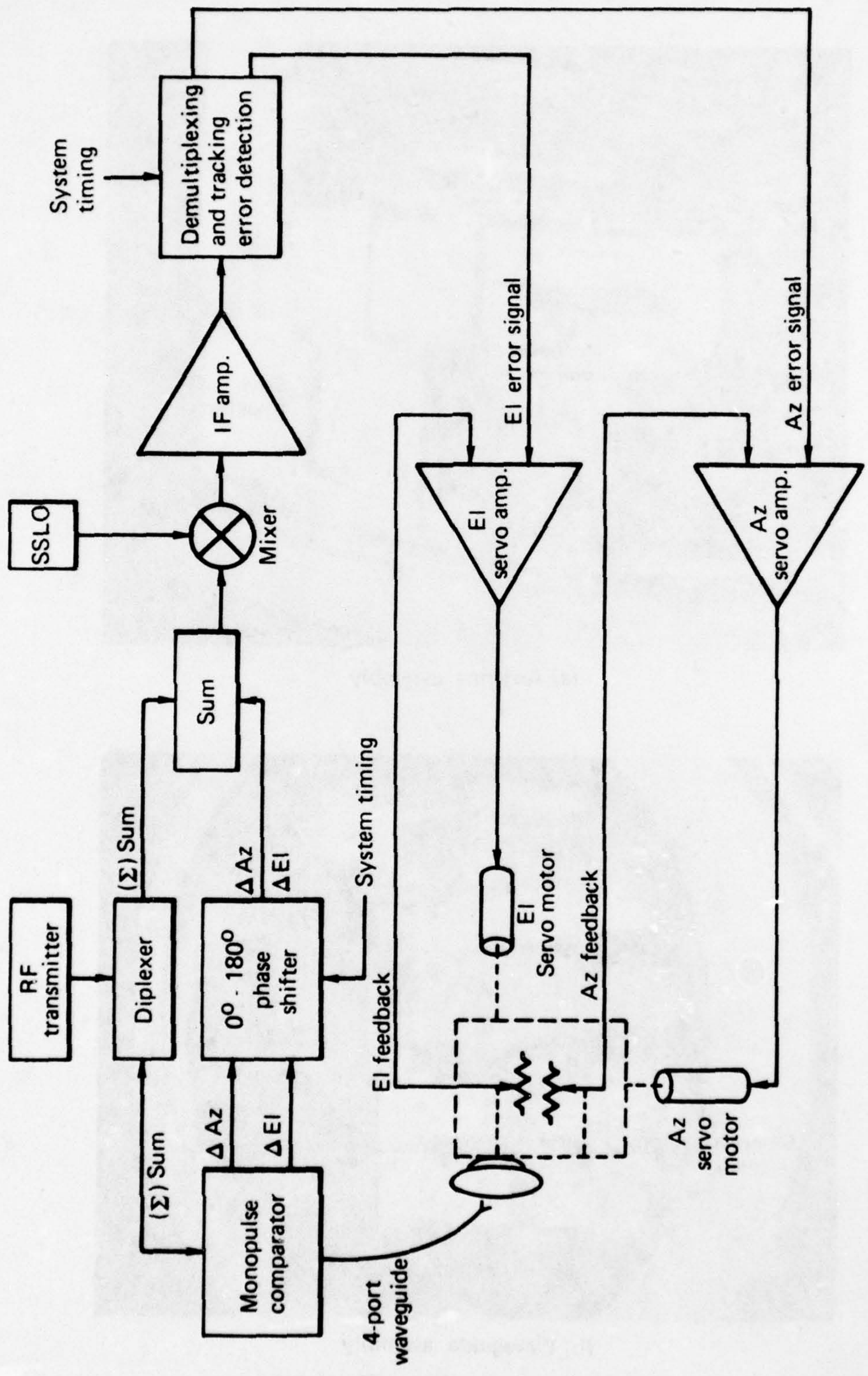
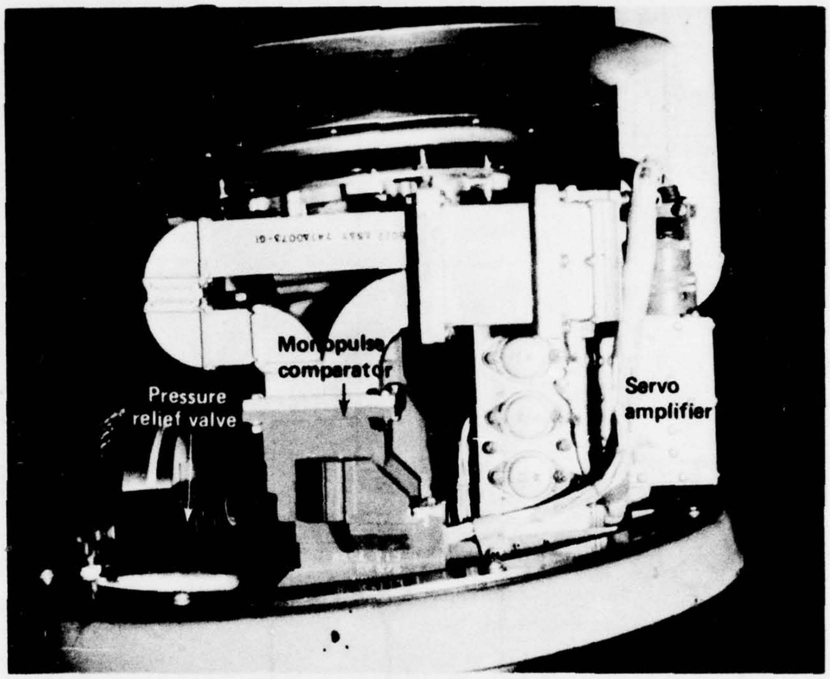
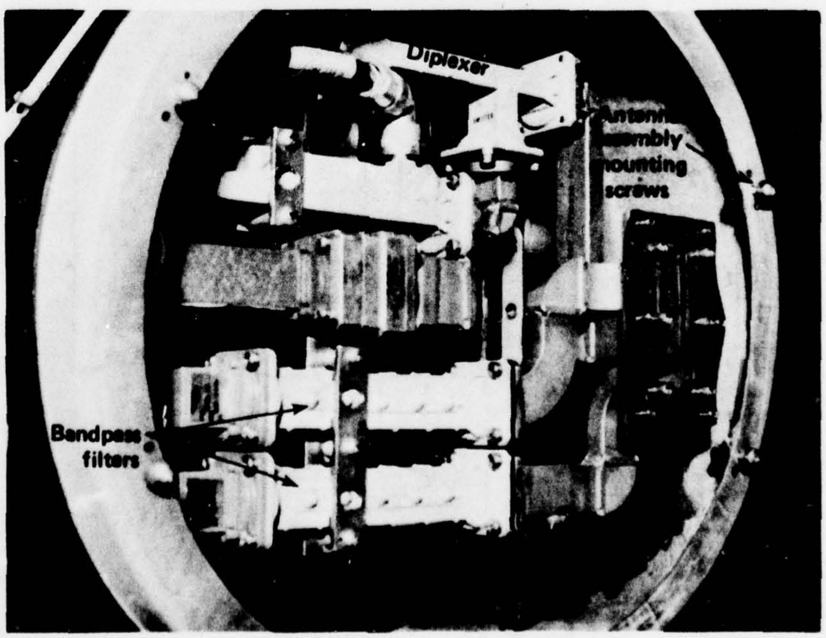


Fig. 1 Simplified Block Diagram of the Target Seeker Simulator



(a) Antenna assembly



(b) Waveguide assembly

Fig. 2 The Target Seeker Simulator

initial pointing error. Two command signals (cage and uncage) are used for in-flight operation.

The CW beacon is located at the missile launch site. It transmits downrange a 10-GHz, 1-W, CW signal. Beacon antenna beamwidths (30° Az and 10° El) allow for drone trajectory boundaries in altitude: 50 to 2000 ft, and cross range tolerance of ±1000 ft.

A summary of system characteristics is given in Table 1.

Table 1

System Characteristics

ELECTRICAL	
Seeker:	
Lock-on and Track Range:	10 nmi (max) to 5000 ft (min)
Tracking Accuracy:	The peak of the transmitted beam is maintained within ±2° of the line of sight between the target drone and the stationary beacon.
Beacon Output Power:	1 W
Pull-in Capability:	±6° from boresight
Gimbal Limits:	
Azimuth — active control from +20° to -20°	
Elevation — active control from +5° to -15°	
Tracking Memory:	Antenna beam pointing angle maintained within ±2° for signal losses of up to 0.5 s duration.
Roll Response:	Compensation is supplied to maintain ±1° antenna beam pointing accuracy for roll angles up to 30° at roll rates up to 60°/s.
Transmitter:	
Type:	Pulse modulated magnetron
Peak Power:	65 kW
Pulse Recurrence Frequency:	Tunable from 415 to 1450 Hz
Pulse Width:	0.7 μs (fixed)

Table 1 (cont'd)

ELECTRICAL (cont'd)	
Interface:	
Primary Power:	+28 VDC aircraft power 24.5A maximum
Control Inputs:	+28 VDC commands
Prelaunch System on command Transmit command Cage command Uncage command Right turn command Left turn command Standby command	
Telemetry Outputs:	
Beacon signal present (0 or +5 VDC) Antenna azimuth (analog) Antenna elevation (analog) Transmitter power (analog)	
MECHANICAL	
Weight:	90.2 lb
Volume:	Approximately 3.2 ft^3 depending on drone installation.
OPERATING ENVIRONMENT	
Temperature:	Operating -15°C to +71°C
Altitude:	Operating, sea level to 20 000 ft Nonoperating, sea level to 50 000 ft

3. SUBSYSTEM DESCRIPTION

The target seeker simulator is composed of a transmitter, antenna assembly, receiver, beacon, and a radome. A brief description of each of these major subsystems is given in the paragraphs that follow. Photos of the subsystems are shown in Fig. 3. A more detailed description of the subsystems is provided in Appendixes A through F.

TRANSMITTER

The target-seeker-simulator transmitter is a modified IEE. It is a pulse-modulated magnetron with the following characteristics:

Frequency: I band, mechanically tunable prior to flight

Peak power: 65 kW

Pulse width: 0.7 μs (fixed)

PRF: 415 to 1450 Hz, mechanically tunable prior to flight

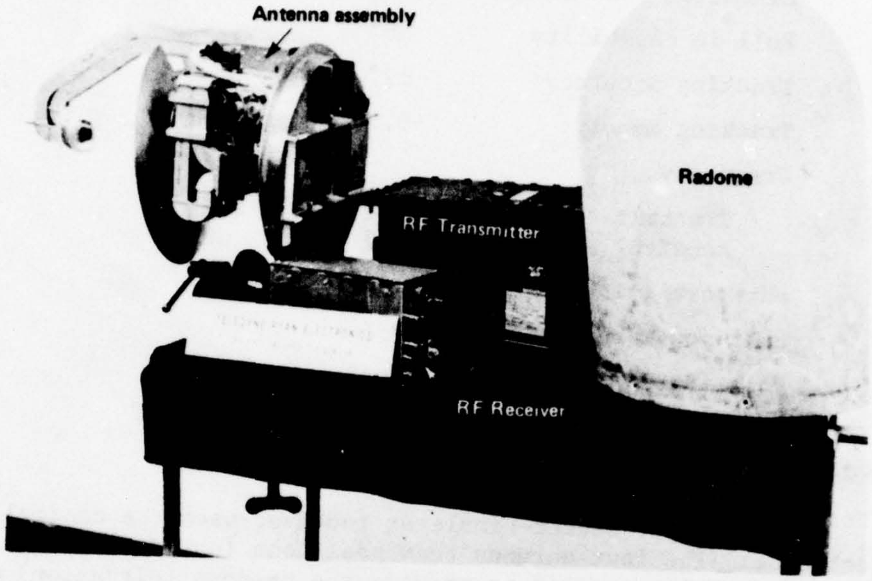
Weight: 44 lb

The flight controller remotely commands the unit to radiate. The transmitter is operable over the complete flight profile of the BQM-34A drone and is operated without the aid of refrigerated air when it is airborne.

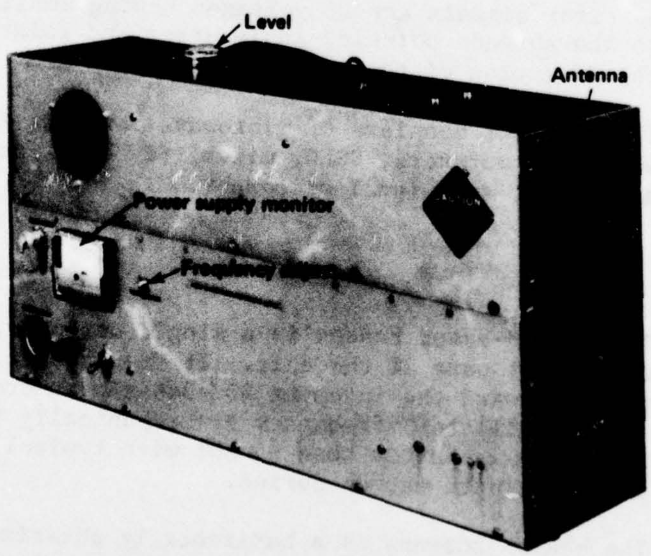
ANTENNA ASSEMBLY

The seeker-simulator antenna is a fixed-feed, moving-dish antenna. A fixed-feed, moving-dish design was selected so that rotary joints would not be needed. The antenna is mounted on a two-bar linkage-and-gimbal assembly from a production Standard Missile.

The assembly (including antenna, gimbal, and servos) has three modes of operation: cage, track, and memory. In the cage mode, the antenna position is fixed with respect to the aircraft. In the track mode, the antenna beam position is controlled from the error signals developed by the receiver. Switching between the cage and track modes is controlled by the flight controller. The memory mode is automatically entered from the track mode whenever the received signal is too weak to provide a reliable error signal. The antenna assembly has the following characteristics:



(a) Component units



(b) CW beacon

Fig. 3 Target Seeker Simulator

Azimuth beam limits:	±20°
Elevation beam limits:	±15°
Pull-in capability:	±6°
Tracking accuracy:	±2°
Tracking memory:	0.5 s (duration)
Frequency:	
Transmit	9.2 to 9.5 GHz
Receive	9.9 to 10.1 GHz
Sum-port gain:	26 dB
Half-power beamwidth:	≥7°
Polarization:	horizontal

RECEIVER

The target-seeker-simulator receiver uses the conical scan technique. The four antenna beam positions (up, down, right, left) are sequentially sampled to provide the up-down (elevation) and right-left (azimuth) error signals to the antenna assembly. AGC provides a constant-error scale factor that is independent of signal strength. The receiver produces three output signals: beacon signal present, azimuth error, and elevation error. The azimuth and elevation error signals are DC voltages having amplitudes proportional to the antenna pointing-angle error and polarities that indicate the direction of the error.

The receiver consists of microwave bandpass filters, azimuth and elevation commutators, SSLO, mixer, 60-MHz IF amplifier, Az and El angle decoder, and signal processor.

BEACON

The ground-based beacon is a single assembly, its antenna being an integral part of the unit. It transmits a 1-watt CW signal downrange toward the incoming BQM-34A target drone. The transmitter (Gunn oscillator) frequency is mechanically tunable. Frequency stability is better than ±5 MHz with typical values of ±1 MHz after a 30-minute warmup period.

The beacon antenna is a horizontally polarized 20-dB horn. The horn is positioned in the beacon assembly at a 6° up angle, which places the 3-dB point of the antenna elevation pattern on the horizon.

RADOME

The radome, designed to replace the standard BQM-34A nose cone, is constructed of 0.070-in. thick polyester/resin laminate and is composed of a 15-in. diameter hemisphere connected to a 14-in. cylinder for smooth fairing into the air frame. In order to provide watertight integrity for water recovery of the BQM-34A drone, a gasket and backup ring has been provided to mount the radome to the waterproof bulkhead of the nose cowling.

Insertion loss through the radome is less than 1 dB over both the transmit and receive frequency bands.

4. THEORY OF OPERATION

Missile flight tests against BQM-34A target drones will be conducted as part of the five-inch ASMD missile validation program. The RF portion of the missile guidance system homes on the RF radiation from an enemy antiship missile that is actively illuminating and homing on the firing ship. Therefore, testing the RF portion of the five-inch ASMD missile requires that the target drone carry an RF transmitter to simulate the radiation characteristics of the antiship cruise-missile seeker.

In order to provide realistic active-seeker signal strength it is necessary to keep the target-seeker-simulator antenna pointed at the launch site irrespective of the drone movement. This is achieved by having a ground-based beacon at the launch site and a passive receiver in the drone, that time shares the transmitter antenna. The receiver activates the antenna gimbals to keep the antenna beam centered on the beacon. In this way the target seeker simulator is made to appear as an active homing missile, while the drone trajectory can deviate from an incoming course.

SELECTION OF ANGLE-TRACKING SYSTEM

The choice of angle-tracking techniques for use in a given tracking radar system depends on the system requirements. Conical-scan systems, in general, are less complex and less expensive than monopulse systems. However, monopulse systems usually provide superior performance in resolution, accuracy, and data rate. A required $\pm 2°$ tracking accuracy and the fact that the target seeker simulator is tracking a cooperative CW source indicated that there is no significant advantage in choosing a monopulse system over a conical scan system. Use of COSRO (COnically Scan on Receive Only) was chosen because amplitude modulation of the simulator transmitter by conscan was undesirable.

Conventional monopulse systems require three receiver channels, one for the sum signal and one for each of two orthogonal error signals. However, by proper combination and modulation of the error signals, followed by combination of the modulated error signal with the sum signal, it is possible to obtain automatic tracking with a single-channel receiver.

SEEKER OPERATION

In operation the target seeker simulator is connected as shown in Fig. 4. The single-channel method of two-axis angle tracking is accomplished by multiplexing the radar-angle error signals. The Δ angle channels are first combined into a single channel, appropriately shifted in phase, and then combined with the sum (Σ) signal to produce a signal that is amplitude modulated alternately by the azimuth and elevation error signals. The degree of modulation is a measure of the deviation of the target from boresight. This basic multiplexing scheme operates in synchronism with the transmitter PRF, thereby alternately sequencing each of the Δ angle channels by the Az-El switch at one-half the PRF to the 0°-180° phase-shift switch. The 0°-180° phase-shift switch operates in synchronism with the transmitter PRF, thus sequencing the selected Δ angle signal through a 180° phase shifter for one radar repetition period, then bypassing the phase shifter for one period. The resulting alternate addition and subtraction of the Δ signal provides the desired amplitude modulation of the Σ signal. The system timing sequence is shown in Fig. 5.

The resultant amplitude-modulated RF error signal is combined in the mixer with an appropriate LO frequency to produce a 60-MHz amplitude-modulated IF signal. Normalization of this angle information is essential if the information is to be useful as position data. This normalization is accomplished in the 60-MHz IF amplifier and video detector by AGC action resulting in a DC output that is independent of signal strength.

In order to recover the sense of the tracking or boresight error, subsequent circuitry is switched in synchronism with the multiplexing circuits to allow for synchronous demultiplexing of the DC error voltage. The resulting azimuth and elevation error signals are then transferred to the respective servos to provide automatic tracking.

DRONE ROLL COMPENSATION

The BQM-34A drone maintains a fixed altitude (auto-pilot) and is steered in azimuth only. To change the azimuth heading of the drone it is placed in a 30° roll. For either small or large azimuth corrections the mechanics are the same, the drone is put into a 30° roll. The total time in the 30° roll determines the azimuth change.

Two tracking-loop design approaches were investigated to handle this 30° drone roll. The tracking loop could be made fast enough that the change in antenna position caused by the 30° roll

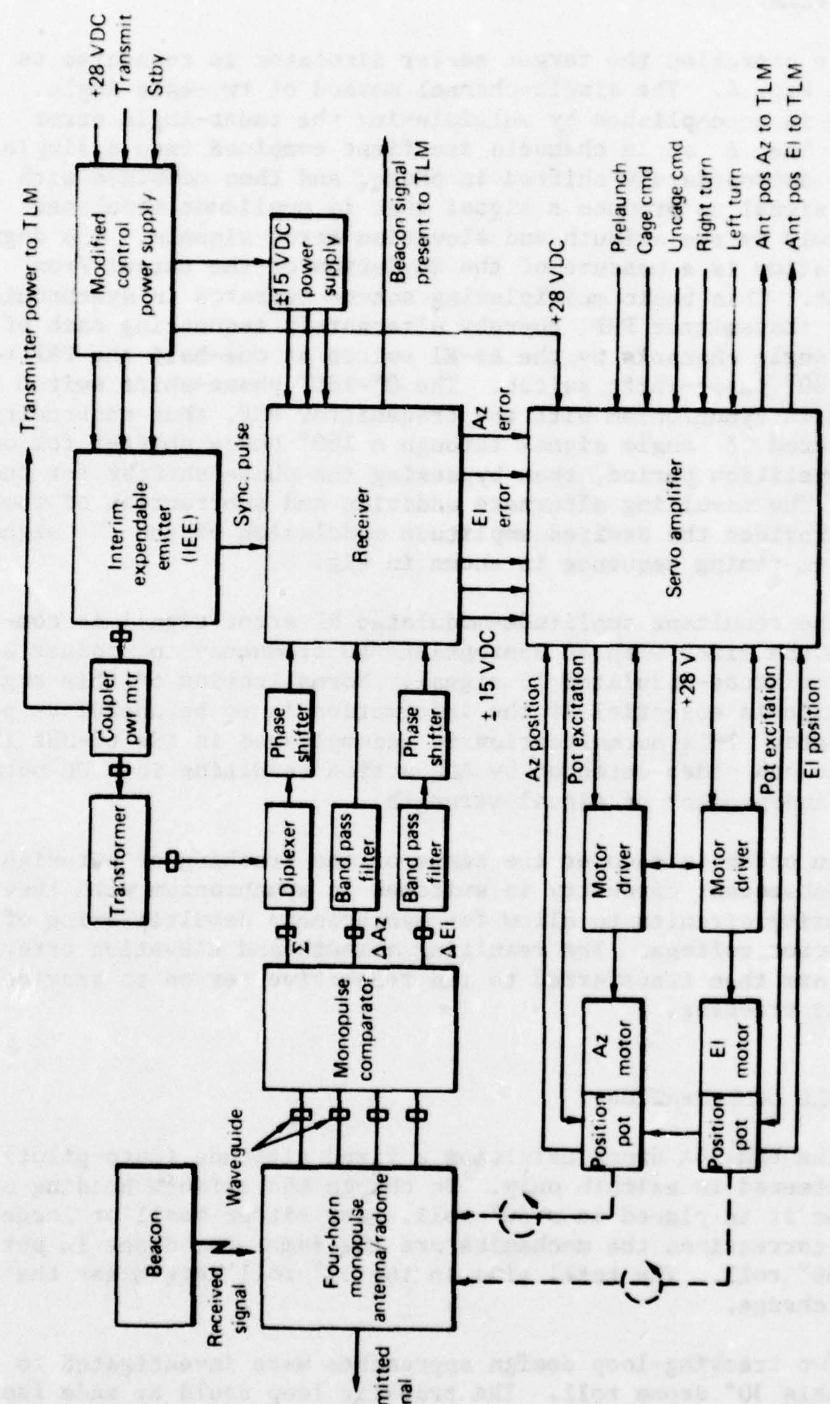


Fig. 4 Detailed Block Diagram of the Target Seeker Simulator

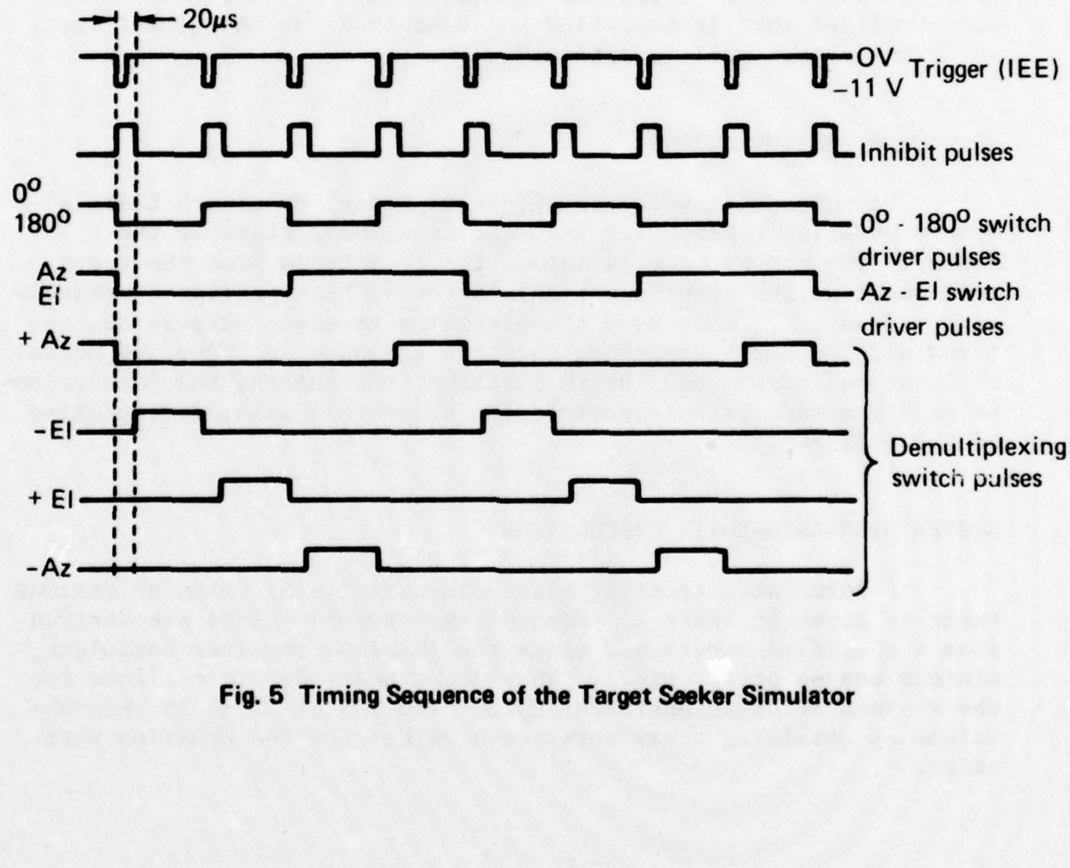


Fig. 5 Timing Sequence of the Target Seeker Simulator

(roll rate, 60-70°/s) could be corrected by the target seeker simulator; however, because of (Ref. 1) multipath it is desirable to have a slow tracking loop (to enable the seeker to coast through the multipath fades). The slow tracking loop (approximately one hertz) was selected, requiring another technique to compensate for the 30° roll.

Figure 6 shows a block diagram of the technique implemented into the seeker simulator design. When the drone rolls, the output of the roll-compensation network and the position data from the antenna are integrated to provide a correction to compensate the antenna beam position for the effects of the roll maneuver. The feedback voltage from the antenna gimbal potentiometer is subtracted from the Δ error and the integrator output, creating an error voltage that is amplified and used to drive the gimbal until an error-voltage null is obtained.

MULTIPATH CONSIDERATIONS

To compensate for loss of signal during multipath fades a memory mode is incorporated into the receiver portion of the seeker. The memory mode is automatically entered from the track mode whenever the received signal is too weak to provide a reliable error signal. In this mode the simulator receiver outputs are removed and the servo amplifier input is grounded so excessive noise will not be introduced. By this method, the antenna beam direction is held constant with respect to the drone roll axis, irrespective of the roll angle.

SYSTEM SIGNAL-TO-NOISE CALCULATION

A calculated receiver signal-to-noise (S/N) ratio at maximum range is given in Table 2. Most of the assumed values are derived from a specified worst-case situation (maximum receiver bandwidth, minimum beacon power, etc.). The beacon beam-edge loss allows for the maximum error in approach angle. The S/N of 11 dB is then obtained by utilizing these worst-case values for the equation variables.

Ref. 1. C. H. Ronnenburg, "RF Multipath Propagation for Low Grazing Angles Applicable to the Target Seeker Simulator," APL/JHU F1B-74U-089, 8 October 1974.

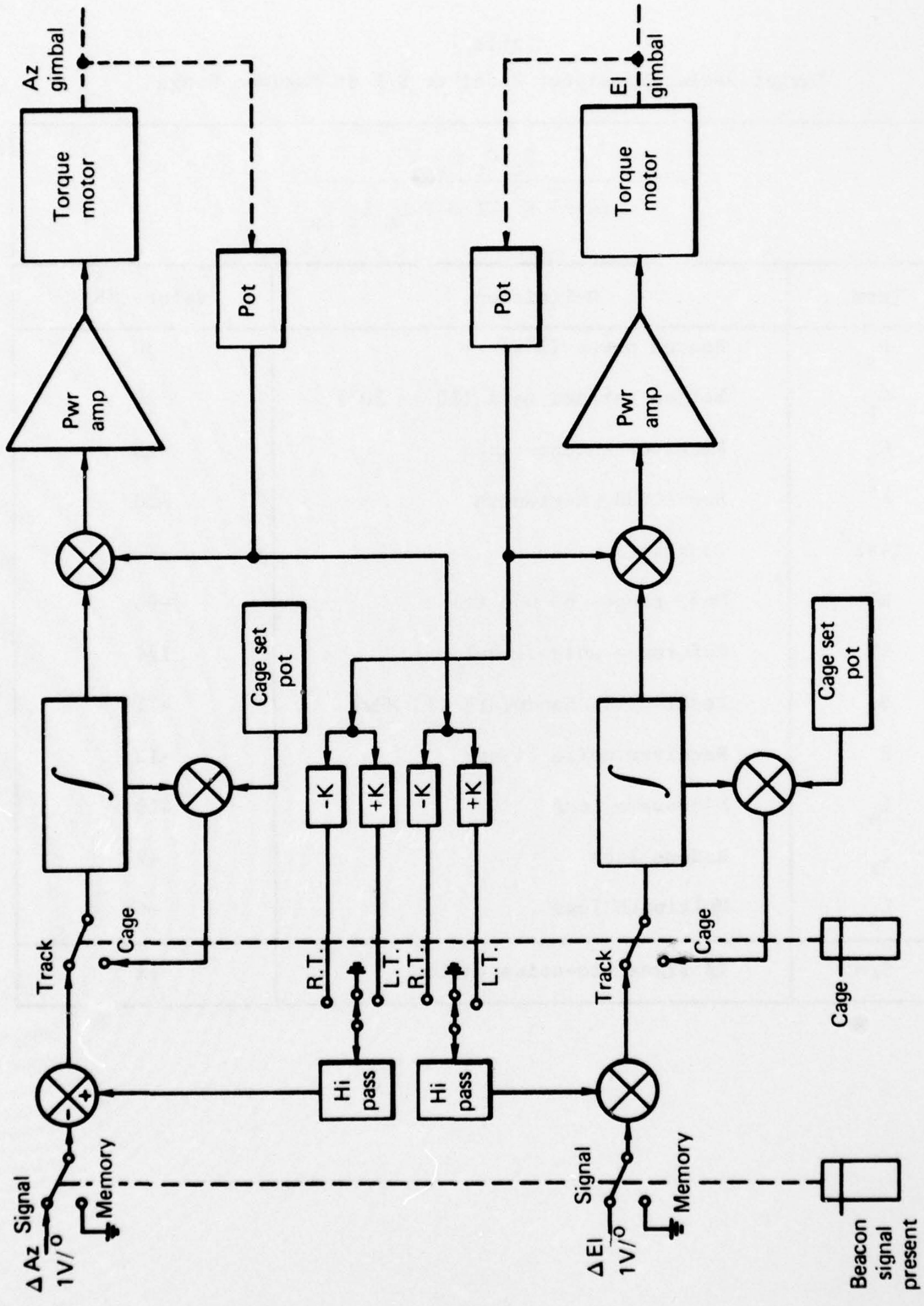


Fig. 6 Block Diagram of the Antenna Servomechanism

Table 2

Target-Seeker-Simulator Receiver S/N at Maximum Range

$$S/N = \frac{P_t\ G_t\ G_r\ \lambda^2}{(4\pi)^2\ R^2\ KT\ B\ F\ L_m\ L_r\ L_p}$$

Term	Definition	Value (dB)
P_t	Beacon power (1 W)	30
G_t	Beacon antenna gain (10° × 30°)	20
G_r	Receiver antenna gain	25
λ^2	Specified wavelength	-20
$(4\pi)^2$	Constant	-22
R^2	Max. range (60 000 ft)	-96
KT	Reference noise level	174
B	Receiver IF bandwidth (13 MHz)	-71
F	Receiver noise figure	-12
L_m	Microwave loss	-10
L_r	Radome loss	-1
L_p	Multipath loss	-6
S/N	IF signal-to-noise ratio	11

3. SYSTEM INTEGRATION

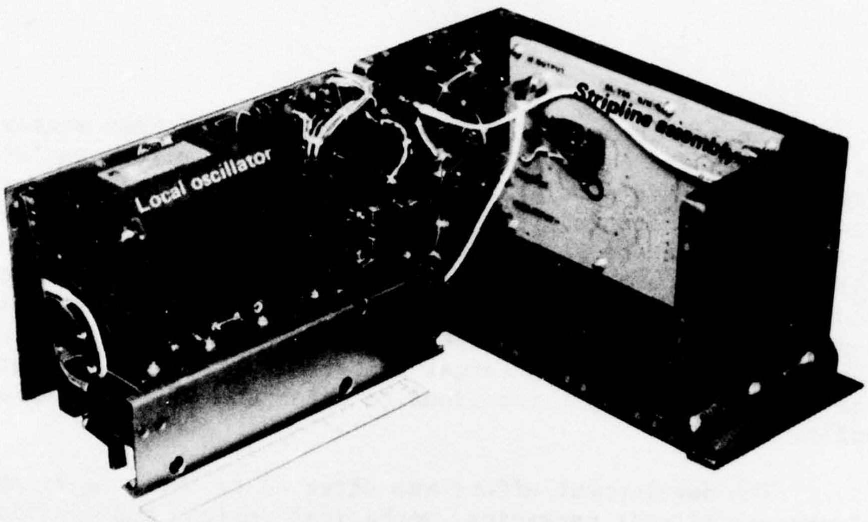
The requirements for integration of the target seeker simulator/drone were established before the design effort was started. The target seeker simulators had to be capable of being installed in the BQM-34A drones presently in Navy inventory. Also, existing equipment was to be used in the installation where practicable. The installation had to be accomplished with minimum modifications to the drone and without disturbance to its intended operations. Input power for the target seeker simulator had to be furnished by the drone. Finally, the target seeker simulator had to meet all the environmental specifications to which the BQM-34A drones are built.

The development effort was directed to three major areas: electronic circuit packaging, mechanical design, and modification to existing drone structures and aircraft installation.

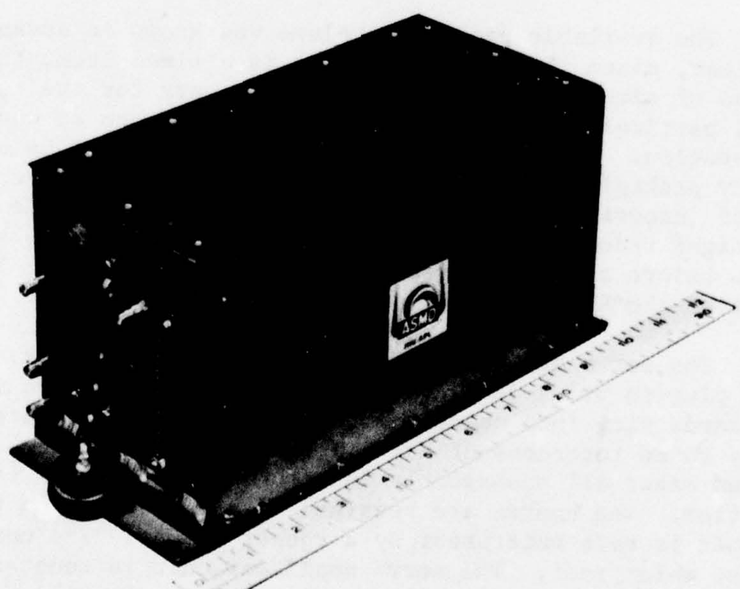
ELECTRONIC CIRCUIT PACKAGING

The available packaging volume was known in advance and it was clear, since the IEE transmitter is a fixed item, that a reduction of size and weight would be necessary for the remaining units, particularly those components that were to be mounted in the nose section. The packaging effort concentrated on using high-density packaging in the construction of the RF receiver. The advent of integrated and stripline circuits made possible the size and weight reduction of the receiver. Photographs of the RF receiver before and after assembly are shown in Fig. 7. The total weight of the RF receiver is under 7 lb.

The servo amplifier (Fig. 2) consists of a case, cover, and three plug-in printed-circuit boards, two of which are identical. The boards plug into chassis-mounted connectors that are wired directly to an interconnect harness that connects to the case connector and makes all subassembly interconnections within the servo amplifier. The boards are retained by a rubber pad on the cover. The unit is made waterproof by a rubber gasket. The case connector is also waterproof. The servo amplifier unit is mounted to a shelf fastened to the bell frame at the rear of the forward compartment.



(a) Before assembly



(b) After assembly

Fig. 7 The RF receiver

MECHANICAL DESIGN

The BQM-34A drone will be operated over water, and in some cases recovery from the water will be necessary; hence, the equipment is made as waterproof as practicable. The antenna section was waterproofed by first modifying the radome, which is equipped with a gasket and back-up ring. The gimbal assembly is mounted to a dished waterproof bulkhead that is mounted to the forward flange of the nose cowling. The gimbal assembly was modified so that waveguides and connectors could pass through the bulkhead. The waveguide and connector passages through the bulkhead are waterproofed also. The servo power amplifiers that drive the motors are mounted to the gimbal (which serves as a heat sink).

The antenna feed and waveguide are pressurized slightly above the atmospheric pressure at sea level to prevent high-voltage/high-altitude breakdown. O-ring seals are used throughout the waveguide runs. A spherically shaped plastic enclosure around the feed maintains pressure through the feed. Pressure leaks have been controlled to provide greater than sea-level pressure for periods longer than 12 hours.

The antenna feed horn with radome was intended to be supported principally by the four waveguides, but structural supports were required. The antenna reflector is mounted to the gimbal, which is compensated by counterweights. The reflector is notched to allow passage of the waveguide.

The equipment compartment is aft of the waterproof bulkhead. The waveguide run passes through the waterproof bulkhead and connects to the monopulse comparator. The transmitter and receiver are mounted on a shelf equipped with supporting brackets.

Only vendor-supplied items that meet military specifications were purchased, to ensure environmental compatibility. To preclude unnecessary delays in the flight schedule, the environmental testing of the flight hardware was limited: one unit of each type being subjected to vibration and shock tests to ensure proper mechanical and electrical design. However, all units requiring pressurization were tested for airtight integrity.

The system was designed to meet the following environmental conditions (Ref. 2):

Ref. 2. H. B. Tetens, "Environmental Specifications for the BQM-34A Drone Electronics and Associated Equipment," APL/JHU F1B-74U-081, 13 September 1974.

Temperature	
Operating	-15°C to +71°C
Altitude	
Operating	Sea level to 20 000 ft
Nonoperating	Sea level to 50 000 ft
Vibration	
Random vibration:	
10 to 2000 Hz; 6g rms, ±10%	One hour per axis, three axes
10 to 100 Hz; 0.006 to 0.02 g^2/Hz	
100 to 1500 Hz; at 0.02 g^2/Hz	
1500 to 2000 Hz; 0.02 to 0.008 g^2/Hz	
Spectrum Tolerance	1.5 dB
Humidity	Three-day duration per mil-std-810B, method 507, procedure 1
Component/System EMI Test	Per mil-std-461/462
Shock	Eighteen impact shocks of 15g half-sine consisting of three shocks in opposite directions along each of the three mutually perpendicular axes, each shock impulse having a duration of 11 ±1 ms

MODIFICATION TO BQM-34A STRUCTURE AND DRONE INSTALLATION (Ref. 3)

Only a modest amount of mechanical work was required to provide mounting for the components of the target seeker simulator. The IEE and receiver mounting brackets were positioned in the nose section and held in place by epoxy adhesive. Clinch nuts were installed on the nose cowling of the drone for installation of the antenna assembly (Fig. 8). The ±15 VDC power supplies were mounted on the drone battery box (Fig. 9). Modifications to the control power-relay box and telemetry were made according to data supplied with the BQM-34A-3-73 target kit. Installation of the required

Ref. 3. H. B. Tetens, "ASMD Tracking Simulator BQM-34A Installation Checkout Procedure," APL/JHU F1B-75U-130, 1 October 1975.

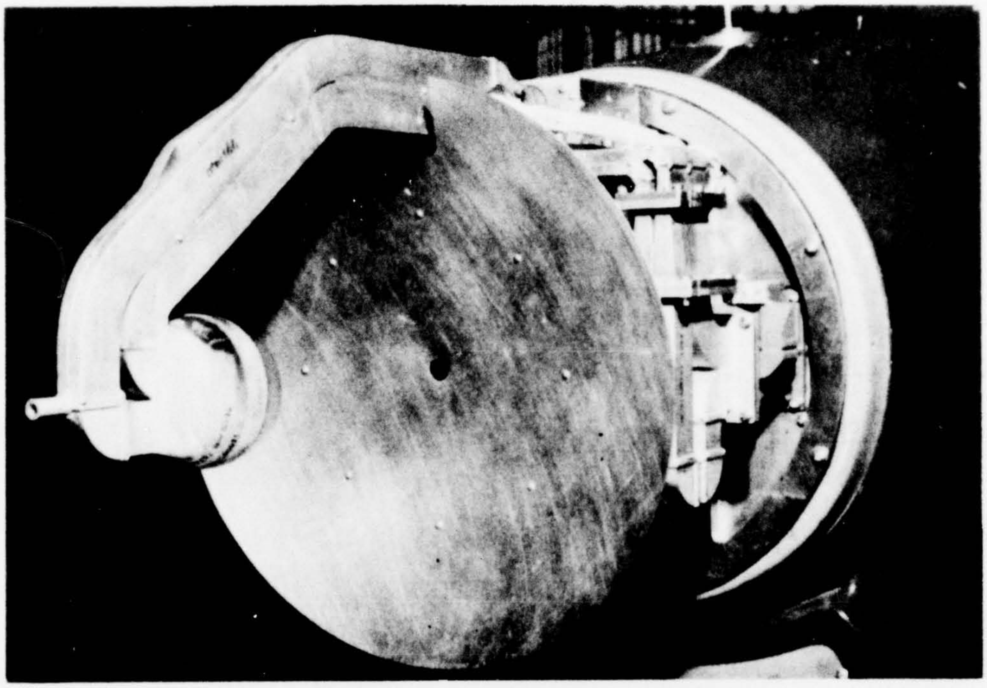


Fig. 8 Installation of the Antenna Assembly

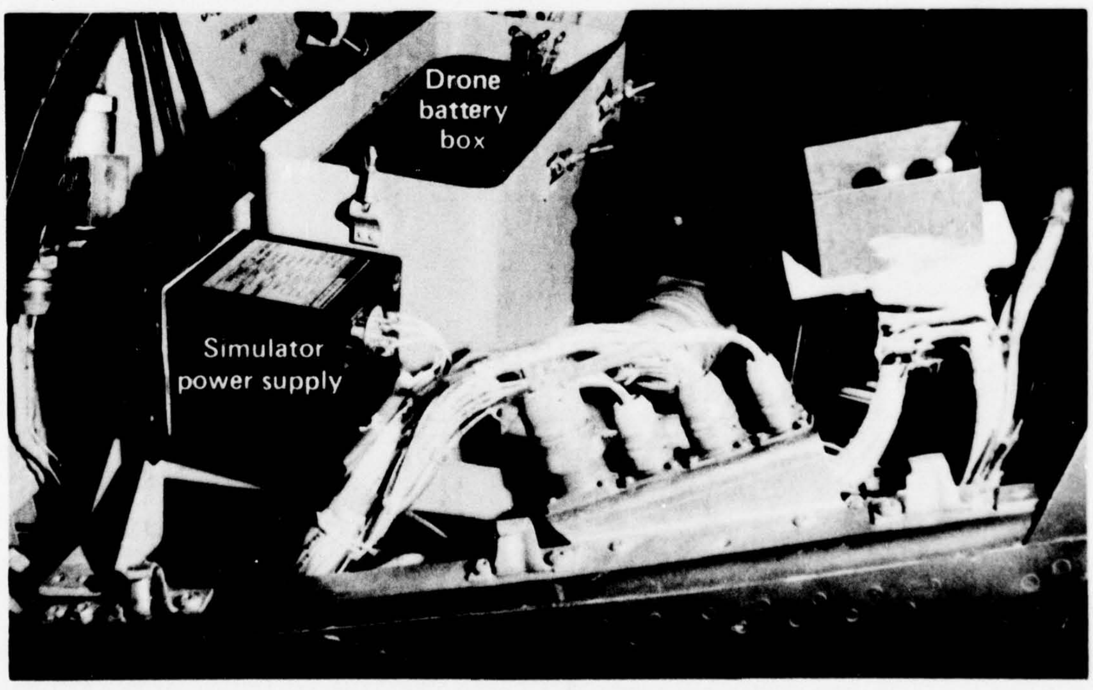


Fig. 9 Installation of the Power Supply

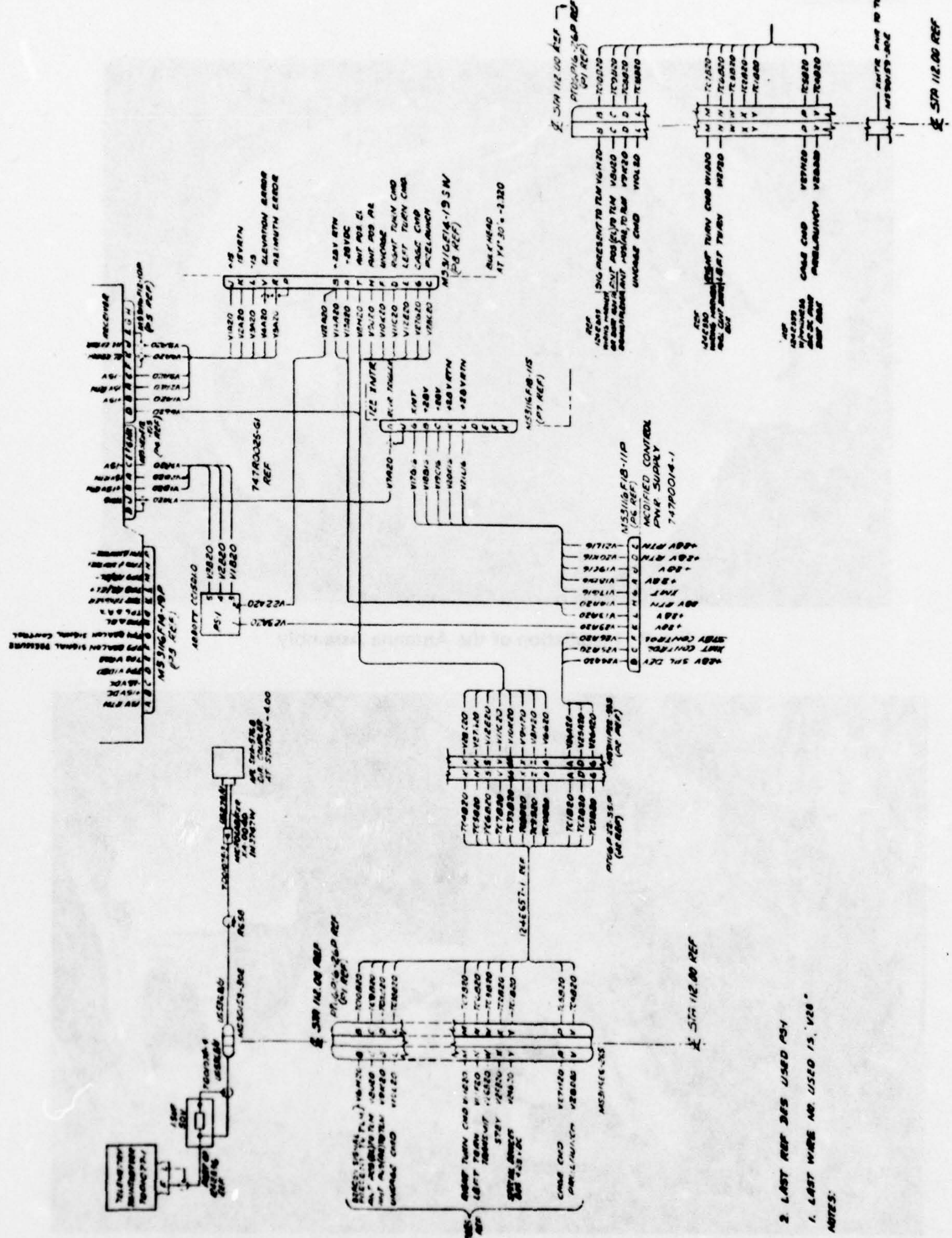


Fig. 10 Wiring Modification of the AN/BQM-34A Drone

associated cabling completed the installation. Figure 10 shows the drone modification.

The completed drone installation with radome in place for flight is shown in Fig. 11.

The overall modifications to the BQM-34A drone are as follows:

1. Remove AN/DRW-29 radio command receiver from nose cowling and relocate in the equipment compartment.

2. Remove scoring rack.

3. Place two fiberglass reinforcing doublers on inside of drone for IEE mounting rack.

4. Add mounting holes, nut plates, and fiberglass reinforcement to cowling lip.

5. Rework harness assembly in the drone as required.

6. Install mounting bracket for the IEE and the target simulator receiver.

7. Install IEE and receiver.

8. Install transmitter-receiver waveguide run.

9. Install bulkhead-gimbal assembly.

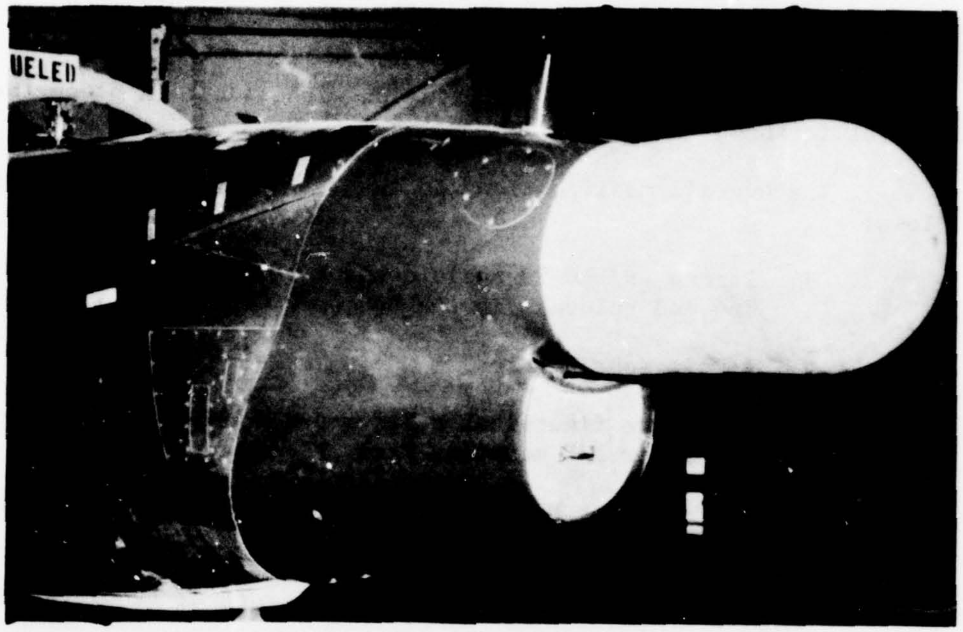
10. Add connector and relay to power control box.

11. Mount simulator power supply.

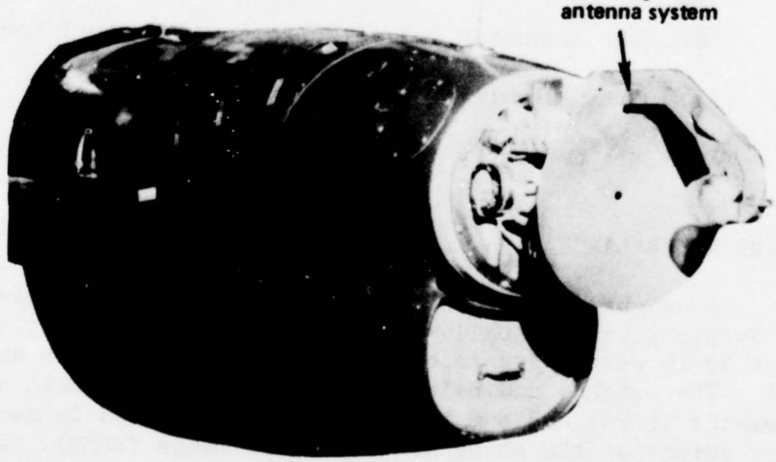
12. Add telemetry transmitter circuitry.

WEIGHT AND BALANCE

A weight and balance analysis of the drone is given in Table 3. Twenty pounds of ballast were added to the chute can area, and about 59 lb were added into the equipment compartment and under the tail. The weights and balance include the pyrotechnic optical plume simulator (POPS) and a C band beacon. The beacon is necessary for range safety at the White Sands Missile Range (WSMR). Approximately 86 lb of equipment is added to the nose area after removal of the scoring rack.



(a) Radome in place



(b) Radome removed

Fig. 11 Complete Installation of the Target Seeker Simulator on the Drone

Table 3

Weight and Balance

	W	X	WX
Weight Empty BQM-34A	1456.70	90.42	131764
Items Removed	(-19.30)		(55)
124K055 Radome	- 5.00		+ 99
124K397 Scoring Rack	- 4.30		- 32
DRW 29 and Mount	-10.00		- 12
Items Added	(254.20)		(21852)
Equip Subassy	0.71		- 8
Gimbal Instl	0.74		- 8
Radome Mod	3.50		- 53
Reflector Assy	1.20		- 18
Gimbal Mod	11.66		-123
Antenna Stop	0.26		- 3
Counterweight	1.08		- 13
Waveguide Assy	1.06		- 18
Radome Horn	0.03		- 1
W/G Assy Cplr to Xfmr	0.44		- 6
Xfmr Assy-STD to X Band	0.17		- 2
Bulkhead	2.67		- 20
Gasket Bulkhead	0.06		0
W/G Clamp	0.02		0
Servo Amp	1.86		- 18
Rcvr/Xmtr Wire	0.53		0
Xmtr Mtg Brackets	1.81		8
W/G Bend	0.31		- 1
Rcvr	7.75		62
Xmtr	40.95		205
W/G Brkt Assy	0.32		- 1
W/G Isol	0.15		- 1
W/G Branched	4.36		- 17
Clamps, Brkts, Clips, etc.	1.78		15
Power Supply	4.80		77
Misc Reinf	2.00		0
DRW 29 and Mount	11.00	138.00	1518
C Band Beacon	7.00	145.40	1018
Ballast-Chute Can	20.00	207.00	4140
Ballast-Under Horiz Tail	59.00	161.00	9499
POPS Kit	67.00		5621
Revised Weight Empty	(1691.60)	(90.84)	(153671)
Oil + Residual Fuel	10.20		238

Table 3 (cont'd)

	W	X	WX
Revised Zero Fuel Weight	(1701.80)	(90.44)	(153909)
Fuel-JP4 — 109 gal	710.00		54336
Revised Gross Weight	(2411.80)	(86.34)	(208245)

A study (Ref. 4) recommends moving the IEE unit (44 lb) to the aft compartment of the drone. If this is done, ballast weights will not be required and overall drone weight will be reduced below 2400 lb.

Ref. 4. R. H. Allen, "Relocation of Interim Expendable Emitter (IEE) in Ryan Drone Missile BQM-34A," APL/JHU F1B-75U-163, 1 December 1975.

6. FLIGHT TESTING OF TARGET SEEKER SIMULATOR

Flight tests were conducted at WSMR on 25 September 1975 to verify the functional adequacy of the target seeker simulator prior to a flight test of a five-Inch ASMD missile. (The drone installation is shown in Fig. 11.) Tests were conducted during a single drone flight, which made six flyover runs.

The flight followed the racetrack pattern shown in Fig. 12. During each flyover the target seeker simulator passively tracked the CW beacon (located at the launch site), and the RF intensity of the target seeker simulator, as measured by an RF monitor at the launch site, was recorded.

The times when the beacon signal indication was received and the gimbal was uncaged are listed in Table 4. Beacon acquisition and tracking were smooth for all six flyovers.

Table 4

Received Signal Times

Run	Beacon Acquisition Signal Time (s)	Beacon Acquisition Signal Range (ft)	Uncaged Gimbal Time (s)	Uncaged Gimbal Range (ft)
1	T-56	48 468	T-27	31 594
2	T-64	54 537	T-47	46 205
3	T-56	48 633	T-38	38 110
4	T-56	49 486	T-45	42 841
5	T-56	49 062	T-46	43 183
6	T-59.5	51 670	T-50.5	45 969

An accurate indication of the target seeker simulator performance is to compare the measured RF power at the launch site against the calculated RF power (assuming perfect tracking). Figure 13 shows the measured RF power for one of the six flyover runs (all six runs were similar). Values for the calculated RF power were obtained by using measured transmitter output power and antenna gain. The bars represent the variation in received power at each data point, due to multipath. The circles in Fig. 13 indicate points where multipath did not occur.

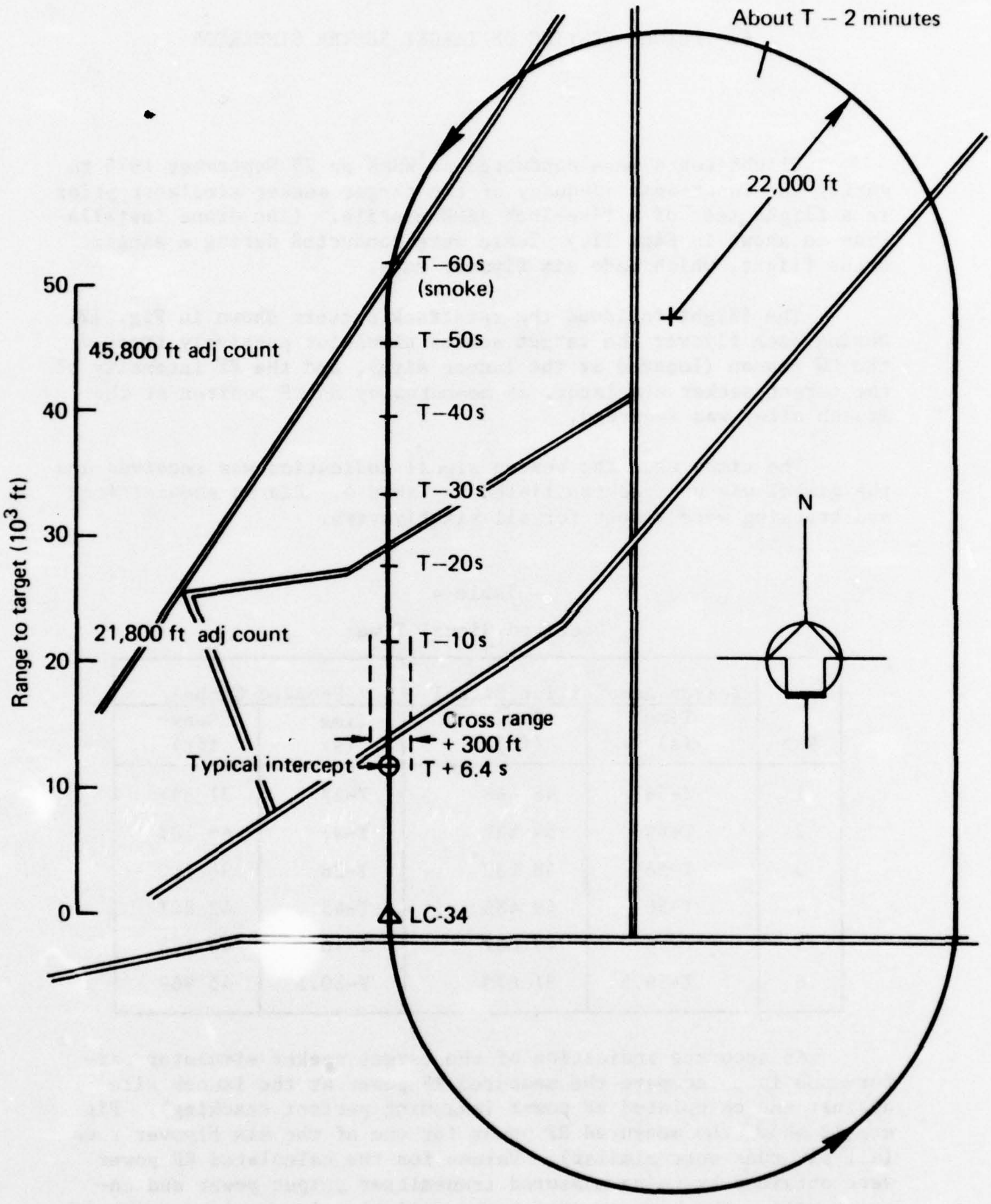


Fig. 12 Racetrack Pattern Flown by Drone

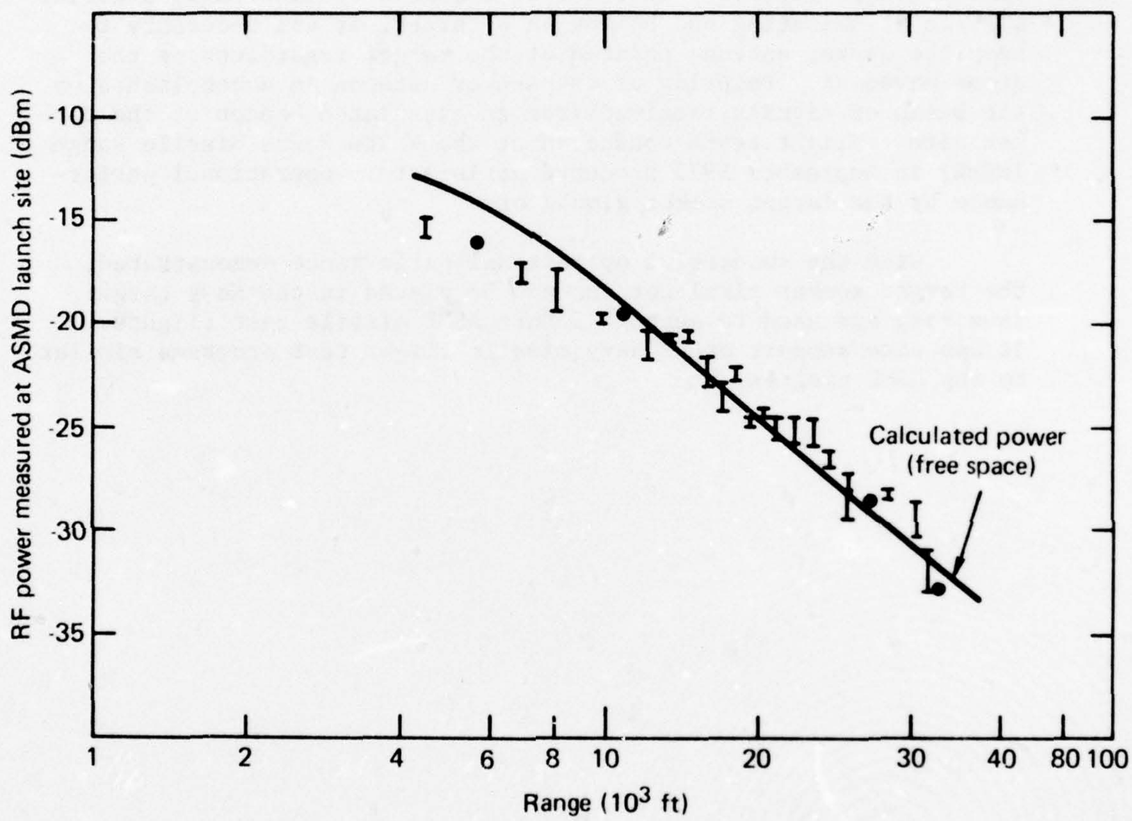


Fig. 13 Measured RF Power for One of Six (Flight 4) Flyover Runs

CONCLUSION

A target seeker simulator has been successfully developed that, when installed in an AN/BQM-34A drone, simulates an active homing cruise missile. In order to simulate realistically a cruise missile illuminating and homing on a target, it was necessary to keep the seeker antenna pointed at the target regardless of the drone movement. Pointing of the seeker antenna is accomplished on the basis of signals received from an associated beacon at the target site. Flight tests conducted at the White Sands Missile Range (WSMR) in September 1975 produced satisfactory operational performance by the target seeker simulator.

With the successful operational performance demonstrated, the target seeker simulator can now be placed in the Navy target inventory and used to support future ASMD missile test flights. It can also support other Navy missile flight test programs similar to the ASMD program.

ACKNOWLEDGMENTS

The authors express their appreciation to all who contributed to the successful development of the target seeker simulator. Special thanks are due A. J. Bassnett and C. Gambrill, Jr. of APL who designed and tested major components of the simulator.

The authors are also grateful for the excellent cooperation of Teledyne Ryan, which shared with APL the responsibility for design and testing. In particular, Mr. D. G. Killion is to be commended for his extensive efforts throughout the program.

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1. C. H. Ronnenburg, "RF Multipath Propagation for Low Grazing Angles Applicable to the Target Seeker Simulator," APL/JHU F1B-74U-089, 8 October 1974.

2. H. B. Tetens, "Environmental Specifications for the BQM-34A Drone Electronics and Associated Equipment," APL/JHU F1B-74U-081, 13 September 1974.

3. H. B. Tetens, "ASMD Tracking Simulator BQM-34A Installation Checkout Procedure," APL/JHU F1B-75U-130, 1 October 1975.

4. R. H. Allen, "Relocation of Interim Expendable Emitter (IEE) in Ryan Drone Missile BQM-34A," APL/JHU F1B-75U-163, 1 December 1975.

5. Final Report for Seeker Simulator Model 747," TRA 74769-1, Teledyne Ryan, San Diego, CA, 23 April 1976.

6. D. R. Marlow, "Design and Analysis of Signal Processing System in ASMD Target Seeker Simulator Receiver," APL/JHU F1B-76U-001, 8 January 1976.

7. E.C. Jarrell, "Specifications of APL Supplied Units for ASMD Tracking Seeker," APL/JHU F1B-75U-059, 28 May 1975.

8. "Qualification Test Procedure for Model 747 Target Seeker Simulator," TRA 74765-1, Teledyne Ryan, San Diego, CA, 20 October 1975.

Appendix A

TRANSMITTER DESIGN

The characteristics of the interim expendable emitter (Fig. 3 in main text) are as follows.

Frequency	I band (tunable)
PRF	415 to 1450 Hz (tunable)
Pulse width	7 μs (fixed)
Peak power output	65 kW
Power input	10-15 A at 28 VDC

Synchronization of gating of the receiver with the transmitter (IEE) off periods is required for proper signal processing. This is accomplished by AC coupling the PRF trigger from the existing IEE timing circuit (Fig. A1) to the receiver signal-processing circuits. The PRF trigger provides sync pulses and inhibits the receiver for 20 μs to minimize the effect of any receiver ringing that might result from the high peak transmitter power.

Before the IEE is placed in the transmit mode there must be a minimum warmup (standby) to prevent receiver damage. A delay timer circuit (Fig. A2) has been added to the transmitter control lines to ensure a minimum warmup of 4 minutes. The delay timer will also recycle the system if there is momentary loss of primary power.

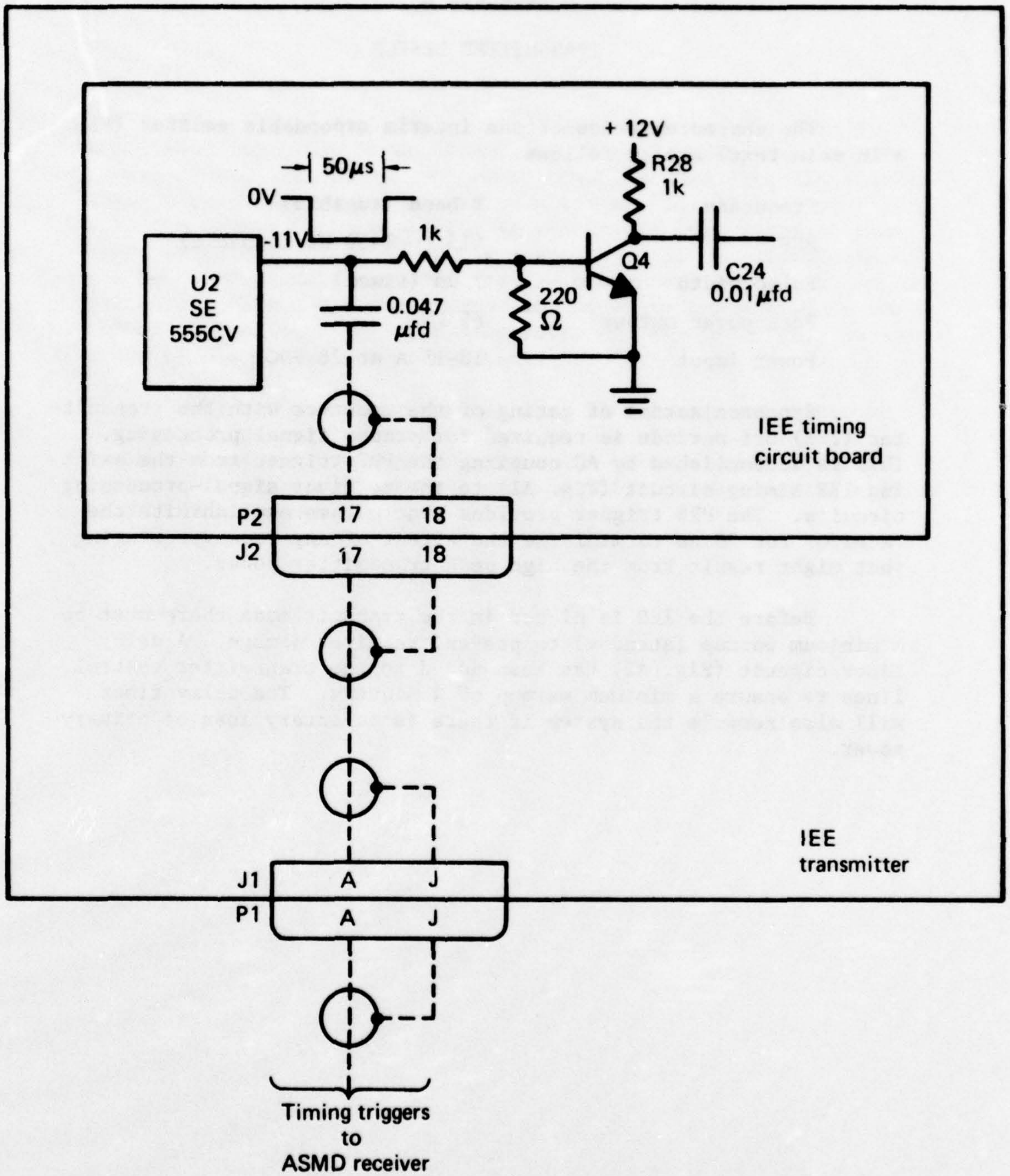

Fig. A-1 Timing Modifications to the Target Seeker Simulator IEE Transmitter

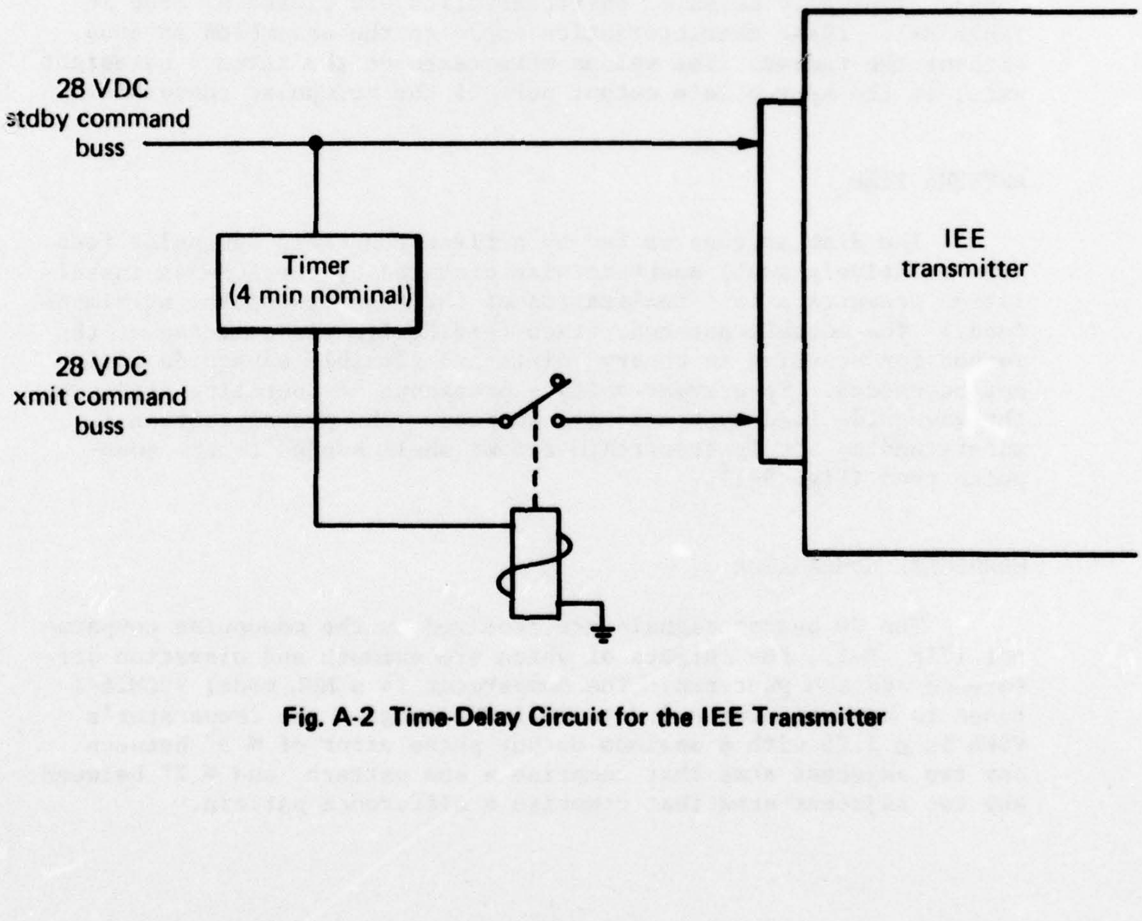

Fig. A-2 Time-Delay Circuit for the IEE Transmitter

Appendix B

ANTENNA ASSEMBLY DESIGN

ANTENNA

The antenna for this system (Ref. 5) is a horizontally polarized dish, fed by a monopulse waveguide horn. A monopulse comparator subassembly is included as part of the antenna.

The antenna assembly operates in both transmit and receive modes. Typically measured characteristics are listed by mode in Table B-1. These characteristics apply to the assembled antenna, without the radome. The values were taken on the antenna boresight axis, at the appropriate output port of the monopulse comparator.

ANTENNA FEED

The dish antenna is fed by a fixed four-horn monopulse feed. (The relatively small aperture size dictated by the BQM-34A installation prevents a full realization of the benefits of the multimode feed.) The movable-antenna, fixed-feed design was selected as the method for scanning so rotary joints and flexible waveguide would not be needed. To prevent voltage breakdown at operating altitude, the waveguide feed system is pressurized. The pressurization is maintained by a polyester/resin radome shell bonded to the monopulse feed (Fig. B-1).

MONOPULSE COMPARATOR

The CW beacon signals are received by the monopulse comparator (Fig. B-1), the outputs of which are azimuth and elevation difference and sum patterns. The comparator is a MDL model 90CM26-1 tuned to operate over a 9.2 to 10.1 GHz range. The comparator's VSWR is $\leq$ 1.25 with a maximum output phase error of $\leq 3°$ between any two adjacent arms that comprise a sum pattern, and $\leq 2°$ between any two adjacent arms that comprise a difference pattern.

Ref. 5. "Final Report for Seeker Simulator Model 747," TRA 74769-1, Teledyne Ryan, San Diego, CA, 23 April 1976.

Table B-1

Antenna Characteristics

Transmit Mode:	
Frequency bandwidth	9.2 to 9.5 GHz
Sum-port gain	27.5 dBi
Az/El beamwidths	7.2° at 23.0 dBi level
Sidelobe level	≥17.5 dB below main lobe
Polarization	Electric field, horizontal
VSWR	1.2:1 max
Receive Mode Sum Characteristics:	
Frequency bandwidth	9.9 to 10.1 GHz
Sum-port gain	28.5 dBi
Az/El beamwidths	7° at 23.0 dBi level
Sidelobe level	≥17.5 dB down from main-lobe peak
Polarization	Electric field, horizontal
VSWR	1.5:1 max
Receive Mode Difference Characteristics:	
Frequency bandwidth	9.9 to 10.1 GHz
Difference-port peak gain	23.0 dBi
Az/El null depths	20 dB min below Σ peak
Sidelobe level	≥17 dB min below Σ peak
Polarization	Electric field, horizontal
VSWR	1.5:1 max

RADOME

The thin-wall radome designed for the target seeker simulator is shown in Fig. 3 (in main text). The radome is 0.070-in. thick polyester/resin laminate composed of a 15-in. diameter hemisphere connected to a cylinder. The radome diameter allows for smooth fairing into the airframe. Since the BQM-34A drone will operate over water, recovery from the water will be necessary in some cases; the radome was waterproofed by the addition of a gasket

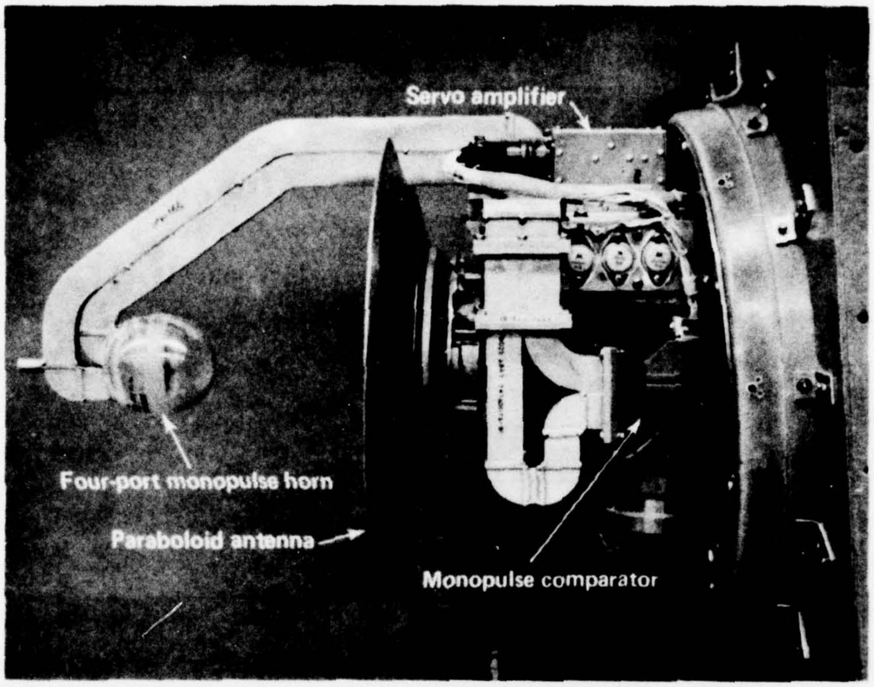

Fig B-1 Target Seeker Simulator Antenna Assembly

and backup ring. A dished waterproof bulkhead was mounted to the forward flange of the nose cowling and outfitted with a pressure relief valve for equalization of pressure changes due to altitude.

Insertion loss through the radome has been measured at < 1 dB over the transmitter and receiver frequency ranges specified.

Appendix C

MICROWAVE ASSEMBLY DESIGN

BANDPASS FILTERS

Waveguide bandpass filters are located in the azimuth and elevation delta and sum outputs of the comparator to protect the receiver from burnout during transmit. The location of these components is shown in Fig. C-1. The bandpass filters are the standard five-section iris-coupled design constructed in aluminum waveguide. For tuning and shaping, a tuning screw (Fig. C-2) is provided for each section. A typical microwave swept frequency response curve, bandpass insertion loss, and typical phase tracking versus frequency between two bandpass filters are shown in Fig. C-2.

DIPLEXER

The required transmit/receive isolation in the sum channel for transmitter radiation is supplied by the diplexer. The waveguide diplexer is a modified series tee combined with the bandpass filter described in the preceeding section. The arm of the series tee containing the bandpass filter was modified in length to place the filter at the proper distance from the tee junction such that the filter impedance, as viewed by the transmitter energy, appeared as an open circuit. Maximum transmit energy passes through the transmit path with an insertion loss of $\leq$0.5 dB. The received signal, as was expected, takes a much larger loss ($\approx$4.0 dB). This loss was considered in the overall system design and conveniently matched the insertion loss through the Az/El and 0/180° switch assemblies. The diplexer outline drawing, is shown in Fig. C-3. The swept frequency measurement for transmit passband insertion loss and receiver passband insertion loss are shown in Fig. C-4.

DIRECTIONAL COUPLER

To provide a positive transmitter "on" signal for telemetering to the drone controller, a 40-dB directional coupler was installed at the transmitter output. The outline drawing of the directional coupler is shown in Fig. C-5. A coaxial diode detection at the -40-dB port provides the transmitter "on" signal to the telemetry.

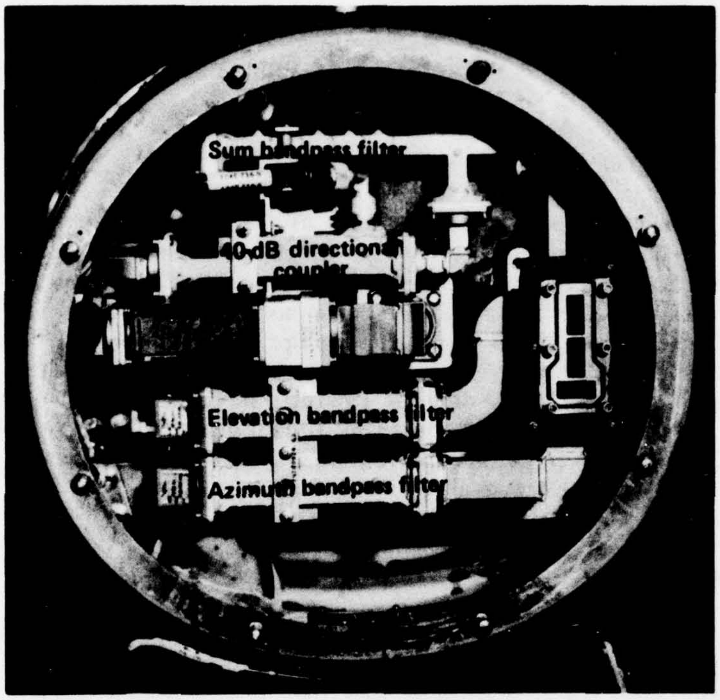

Fig C-1 Target Seeker Simulator Microwave Assembly

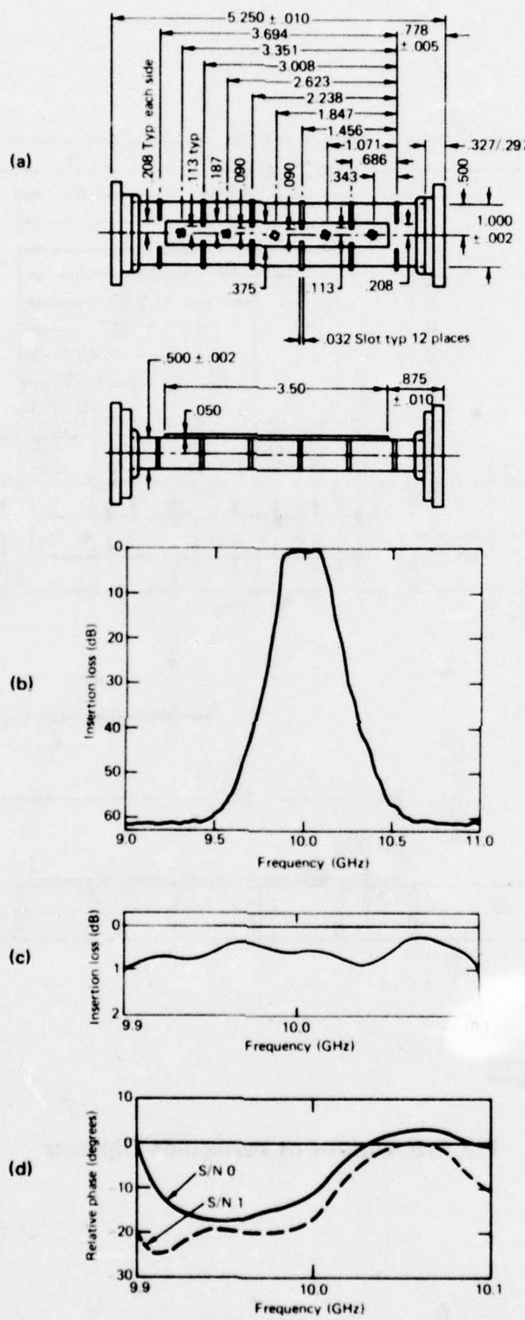

Fig. C-2 Waveguide Bandpass Filter: (a) Mechanical Details, (b) Passband Characteristic, (c) Insertion Loss vs. Frequency, and (d) Phase Tracking vs. Frequency

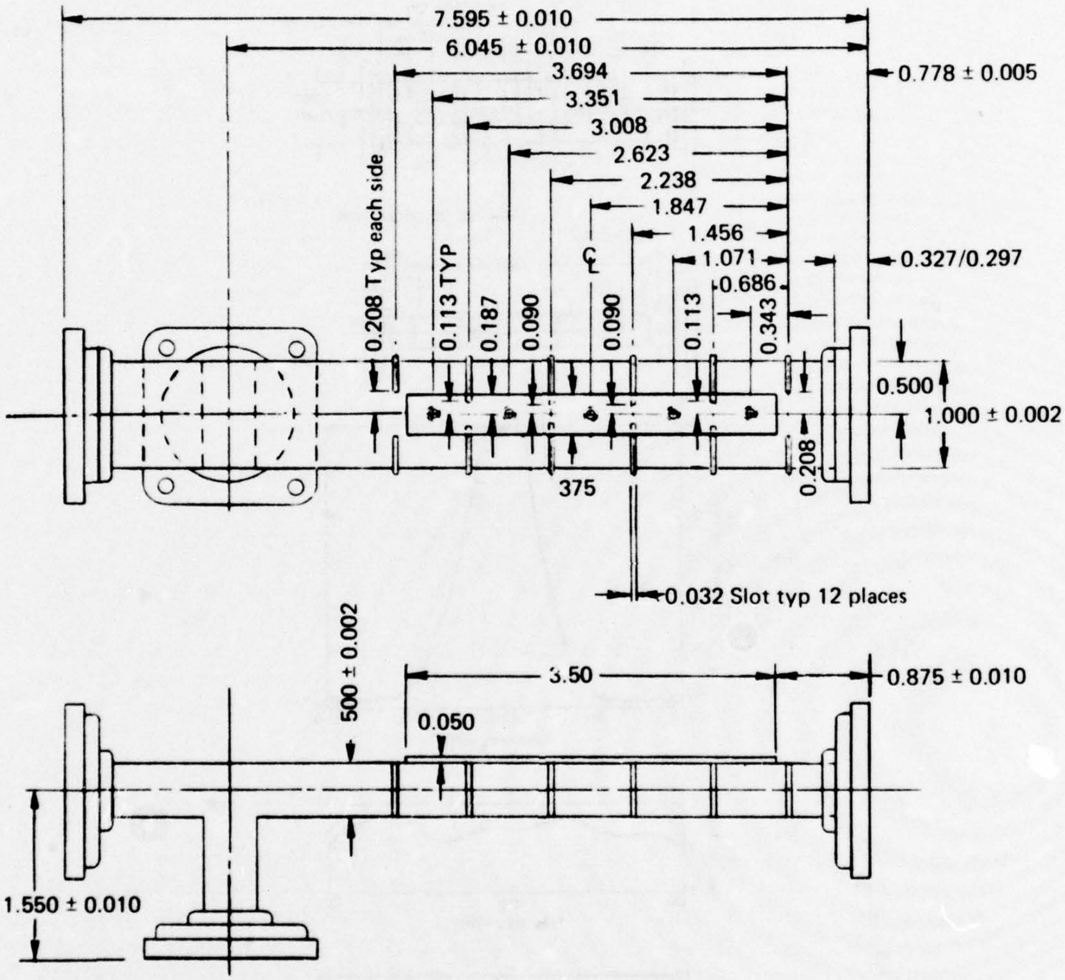

Fig. C-3 Outline of Waveguide Diplexer

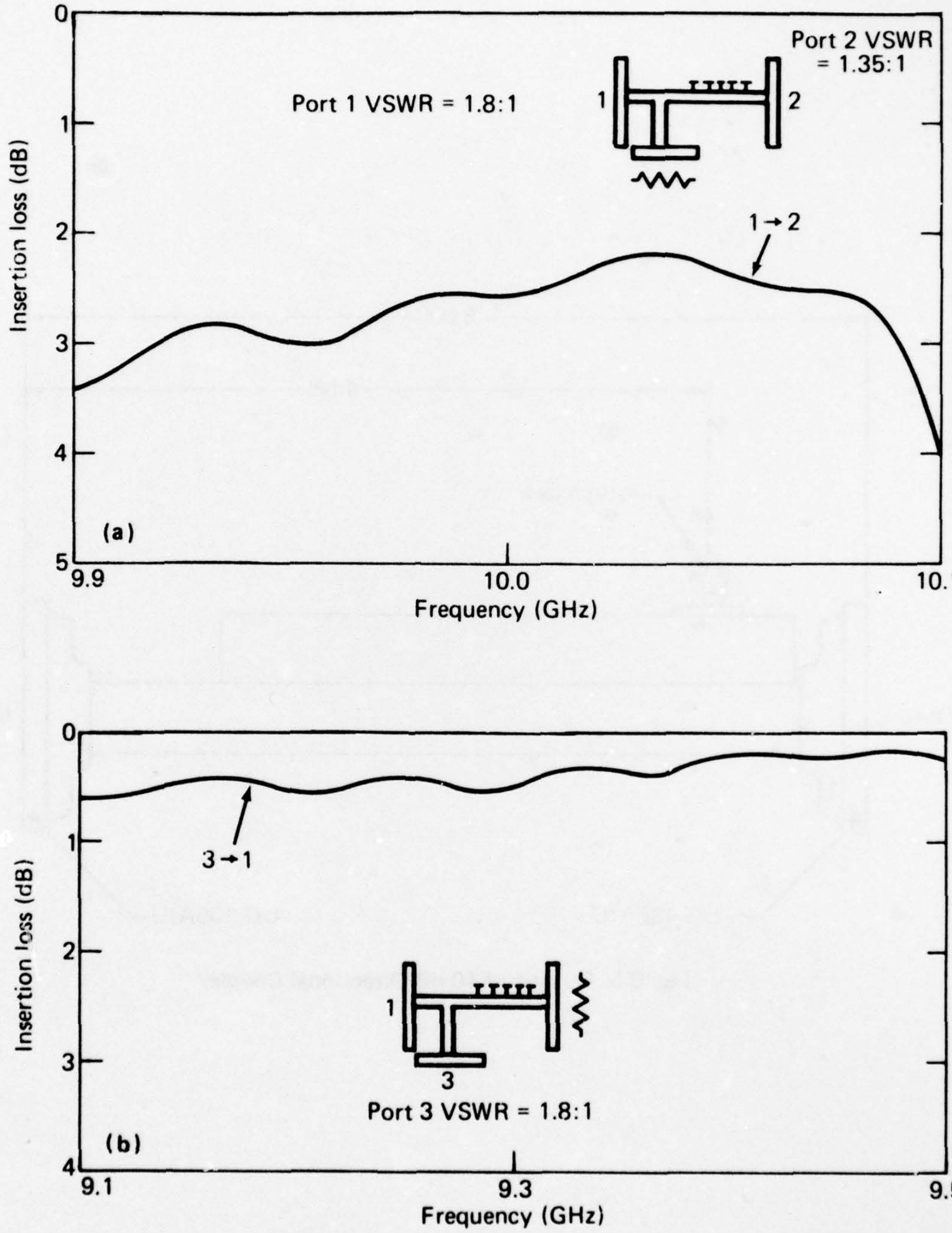

Fig. C-4 Waveguide Diplexer: (a) Receive-Path Insertion Loss vs. Frequency, (b) Transmit-Path Insertion Loss vs. Frequency

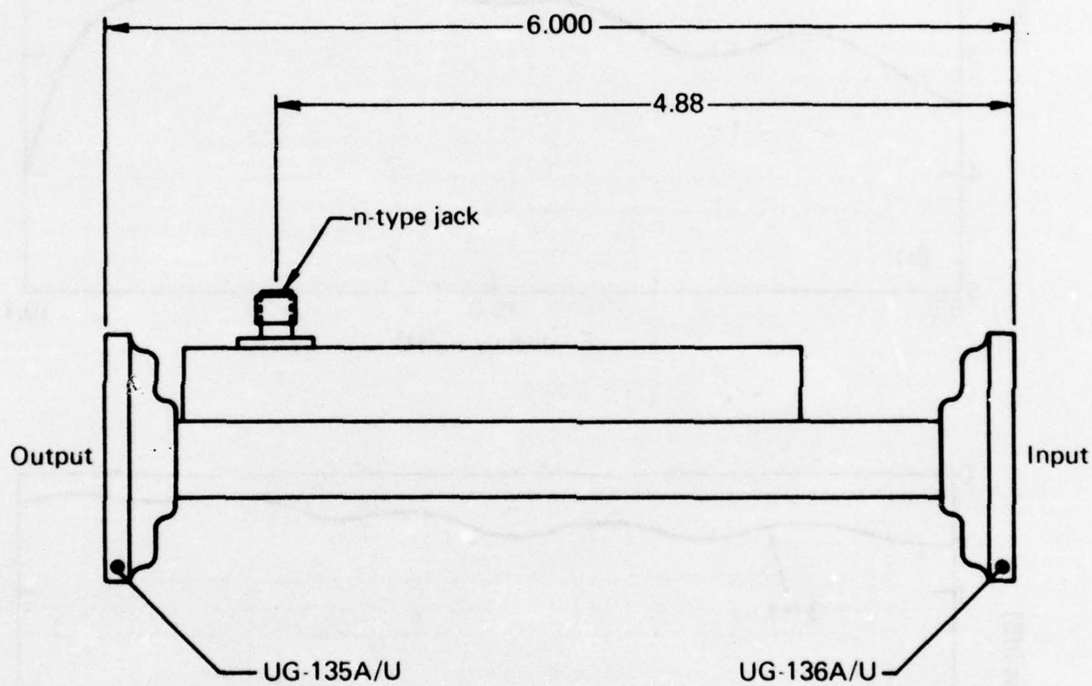

Fig. C-5 Outline of 40-dB Directional Coupler

Appendix D

RF RECEIVER DESIGN

The RF receiver (Ref. 6) processes incoming RF signals and performs the angle-tracking technique (conical scan on receive only) providing two-axis angle track signals. The RF receiver (Fig. D-1) contains the following subassemblies:

1. Microwave stripline
2. Crystal-controlled local oscillator
3. 60-MHz IF amplifier
4. Signal-processing circuit board

Figure D-2 is the overall wiring diagram for the receiver.

MICROWAVE STRIPLINE

The microwave stripline contains three SPDT RF switches, a 3-dB rat race, and a balanced mixer with associated bandpass filters for converting the received RF signal to an amplitude modulated 60-MHz IF signal. The stripline circuit layout is shown in Fig. D-3.

The azimuth and elevation difference inputs are time duplexed by the diode switches. The commercially available switch modules are designed for internal mounting in stripline sandwich thickness totaling 1/8 in.

A 3-dB rat race is used for summing the time duplexed difference inputs with the sum input.

The mixer is a conventional balanced mixer. High impedance matching lines and matching stubs are used to match the diodes over the required frequency band. The IF output is extracted by means of a half wavelength line for IF-to-RF isolation. Bandpass filtering provides the additional isolation between the IF output and the RF and LO ports. Conversion loss for the configuration is 7.5 ±0.5 dB. The finished stripline assembly is shown in Fig. D-3.

Ref. 6. D. R. Marlow, "Design and Analysis of Signal Processing System in ASMD Target Seeker Simulator Receiver," APL/JHU F1B-76U-001, 8 January 1976.

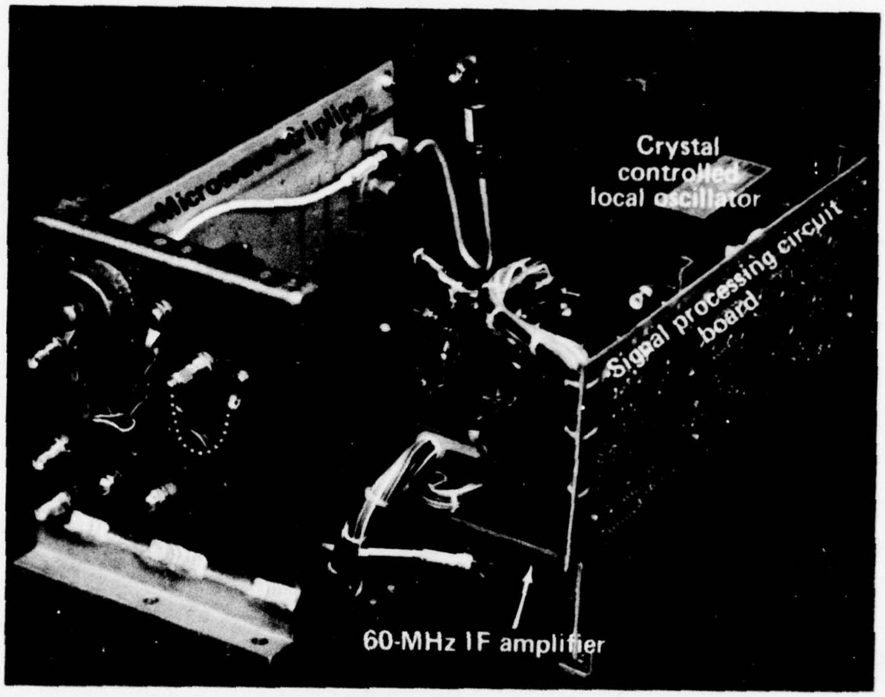

Fig D-1 RF Receiver Assembly

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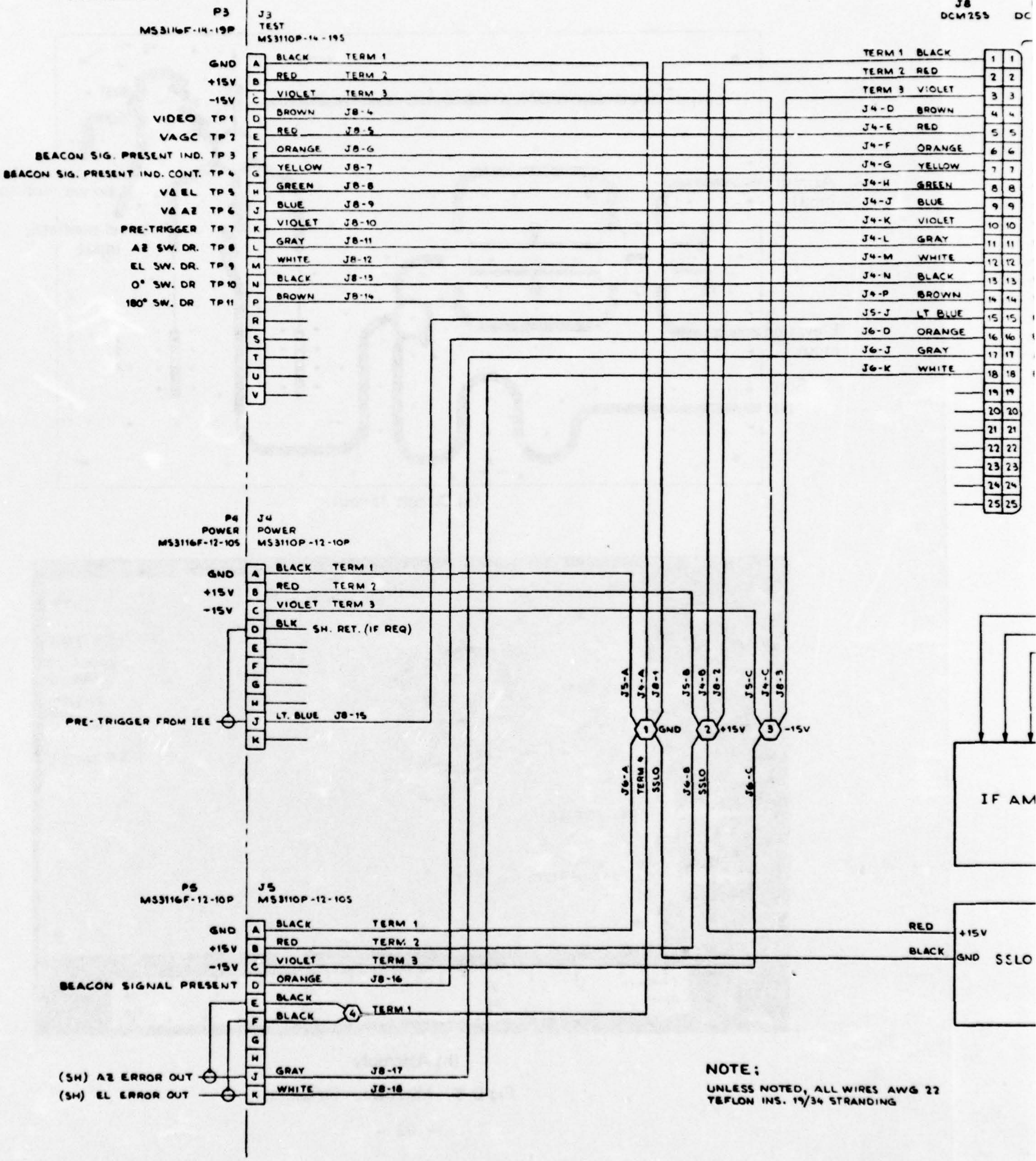


NOTE;

UNLESS NOTED, ALL WIRES AWG 22
TEFLON INS. 19/34 STRANDING

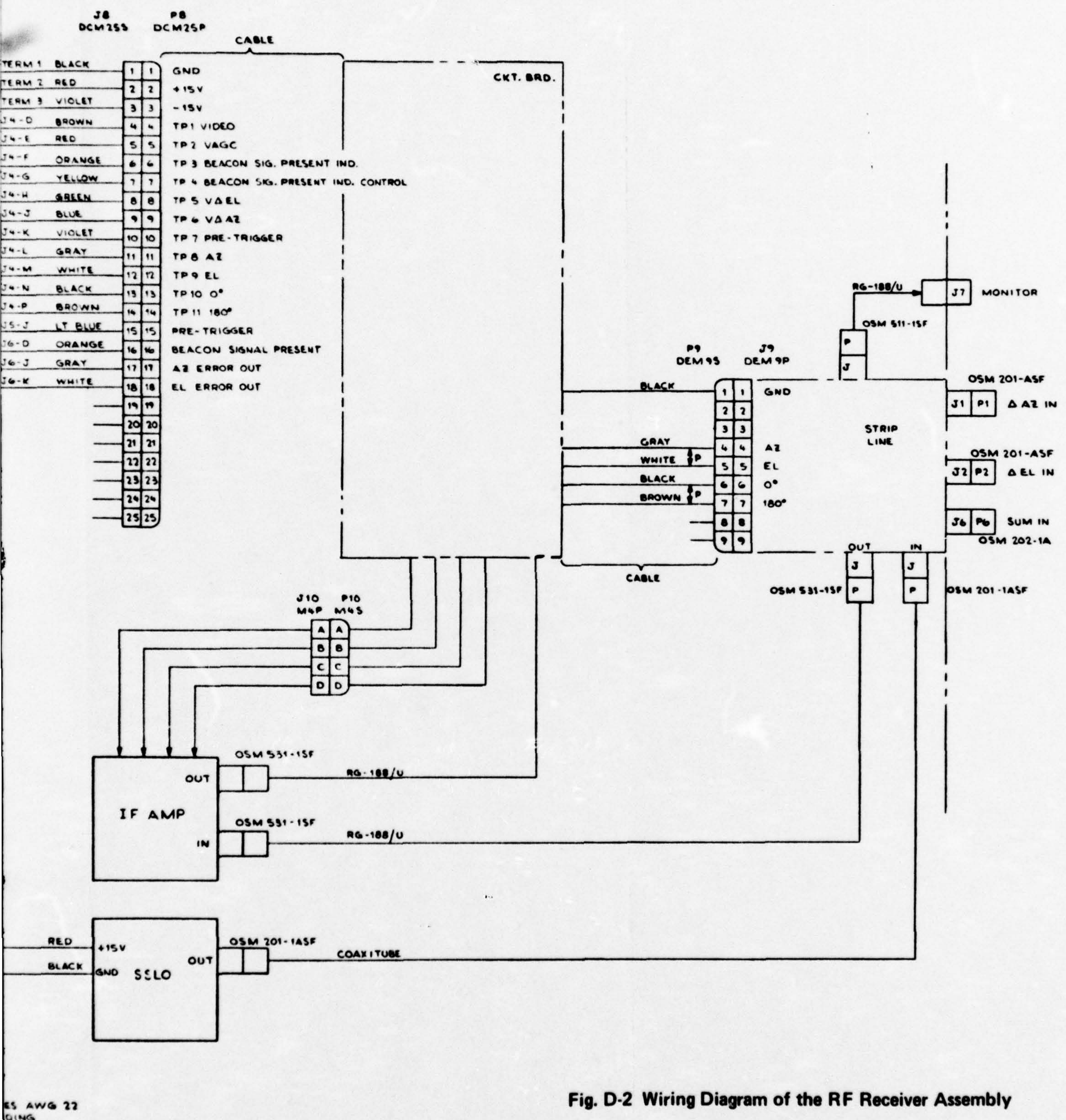
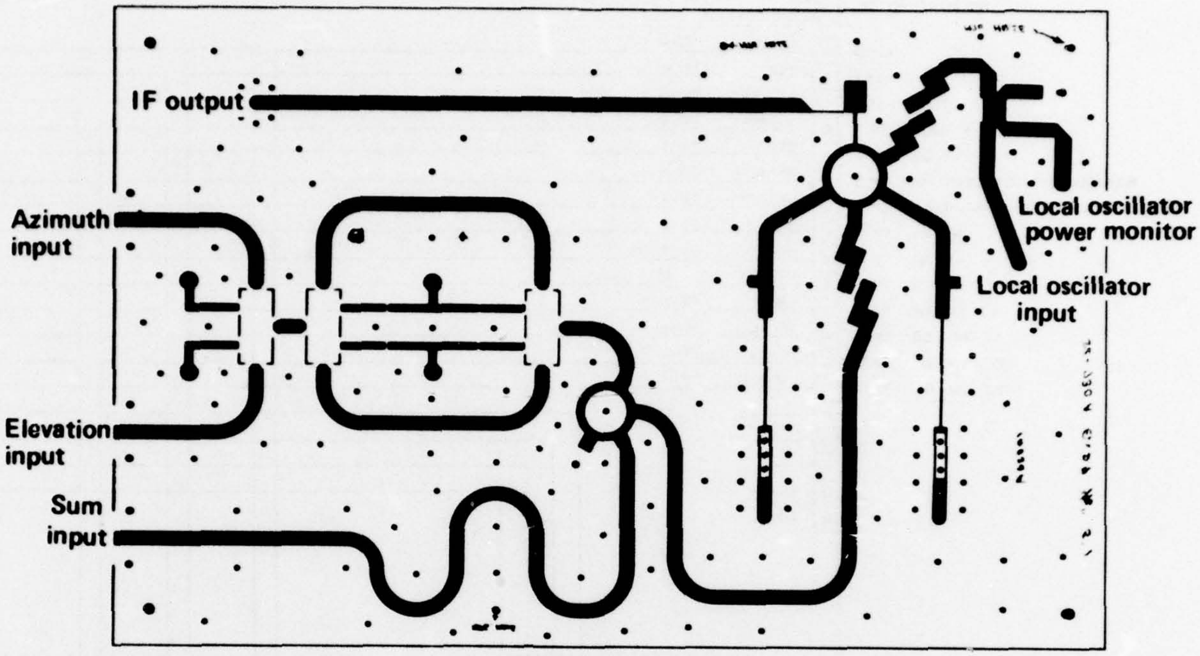
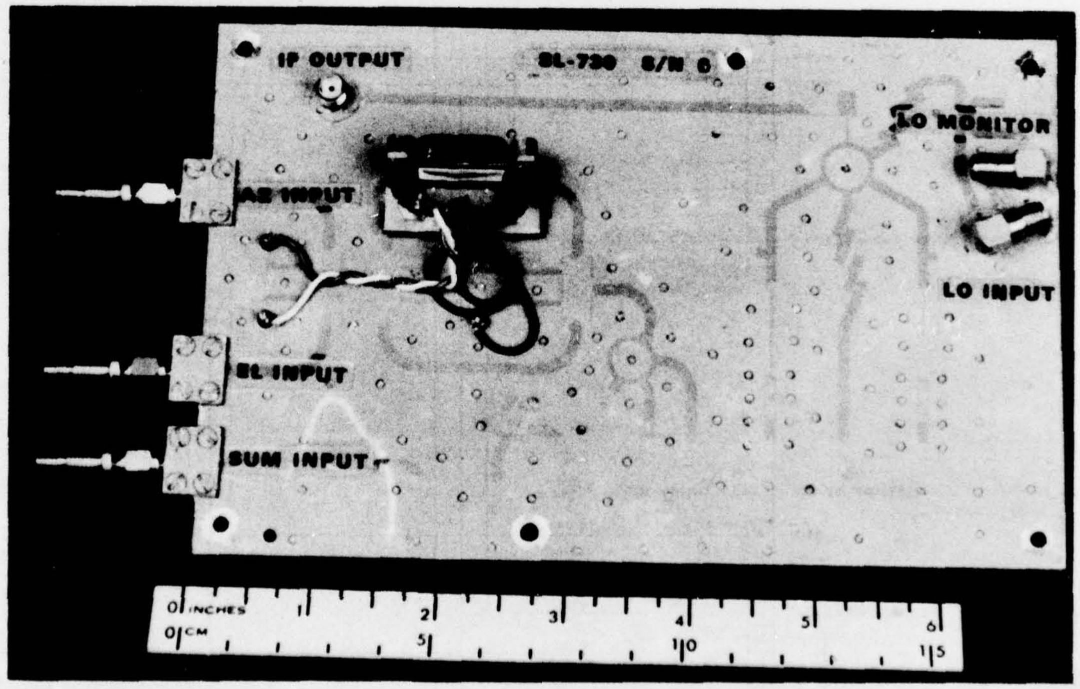


Fig. D-2 Wiring Diagram of the RF Receiver Assembly

2



(a) Circuit layout



(b) Assembly

Fig D-3 Microwave Stripline

SSLO

The LO input is supplied by a fixed-frequency crystal-controlled oscillator (Fig. D-1) having the following characteristics.

RF frequency	10.060 GHz
Power output	10 mW (min)
Crystal frequency deviation	±0.001%
Spurious and harmonic rejection	>40 dB
Output impedance	50 Ω
Primary power	±15 VDC

IF AMPLIFIER

The 60-MHz IF amplifier has the following characteristics.

Center frequency	60 MHz
3-dB bandwidth	10 MHz min, 15 MHz max
Gain, RF-to-video	115 ±5 dB
Video output	1.1 VDC
AGC	50 dB RF, -105 dBm to -55 dBm
Noise figure	3 dB max
Primary power	±15 VDC
Input impedance	15 + j50 Ω

The 60-MHz IF amplifier is shown in Fig. D-4 and its schematic is shown in Fig. D-5.

SIGNAL PROCESSING CIRCUIT

For packaging convenience the signal processing circuit board consists of the following combined circuits.

1. System timing circuit

2. AGC

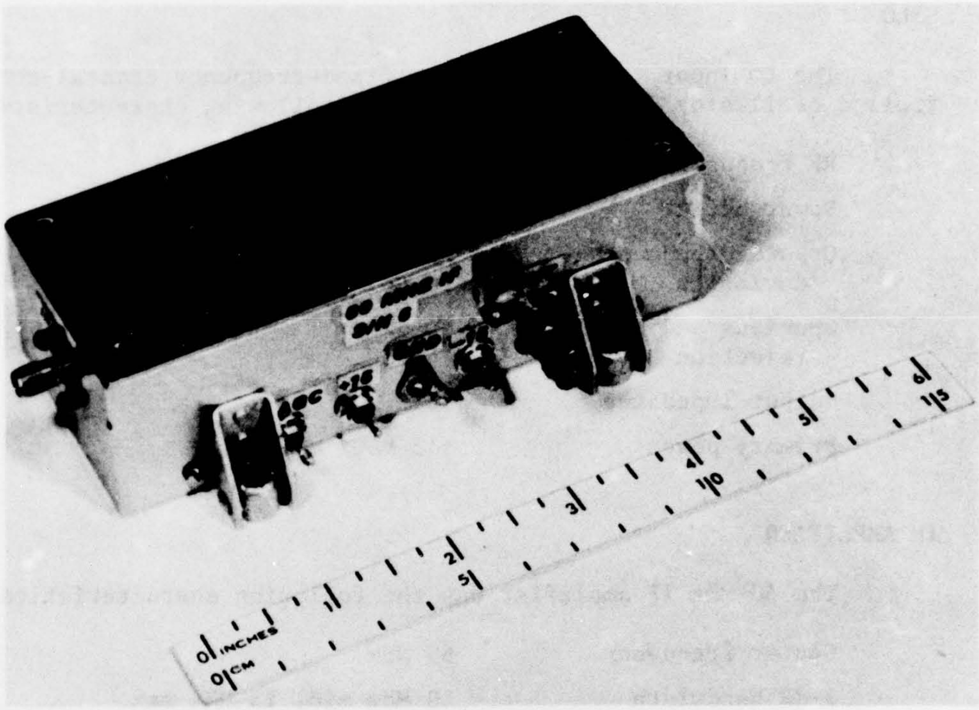


Fig D-4 Sixty-MHz IF Amplifier Assembly

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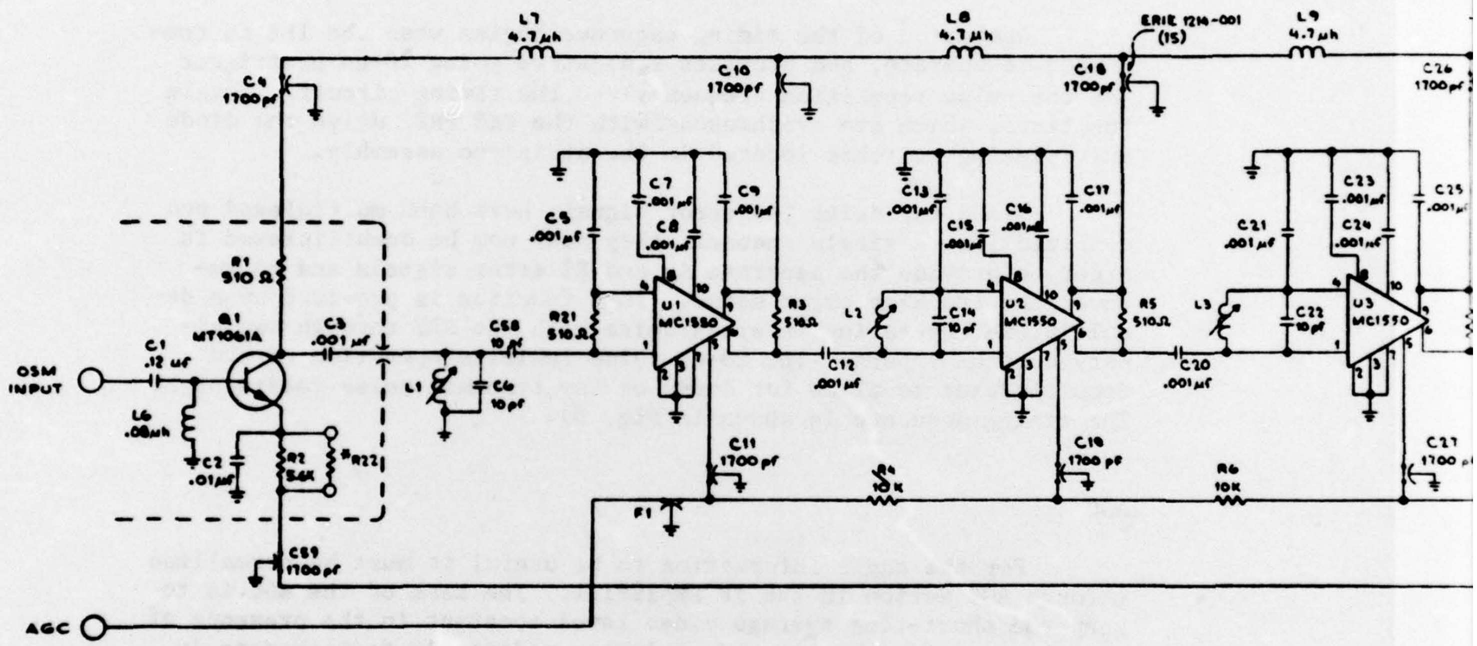
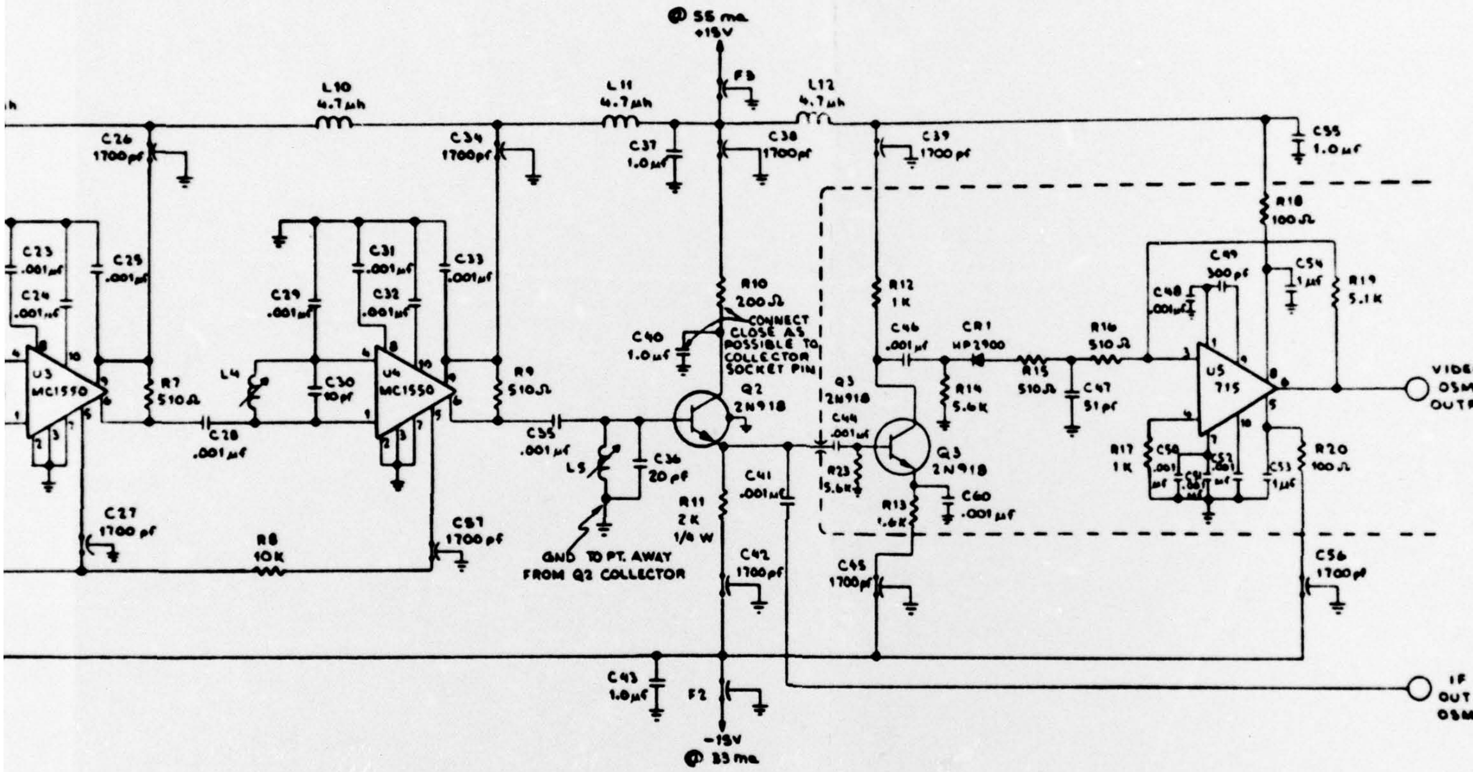
LAUREL, MARYLAND



NOTES:

1. ALL RESISTORS ARE 1/8 W UNLESS OTHERWISE NOTED
2. ALL .001 μf CAPACITORS ARE VITRAMON #VK 23 BX102K
3. L1, L2, L3, L4 ARE PICONICS #8621K6I-00
4. L5, IS PICONICS #8701K6I-00
5. F1, F2, F3 ARE EMI SUPPRESSION FILTERS ERIE #1250-003
6. C1 IS A VITRAMON VK 33 BW124K, 0.12 μf
7. C2 IS A MONOBLOC .01 μf
8. L6 IS 10 TURNS ON PICONICS T12-22 TOROID # 30 BELDSOD WI
9. * R22 IS TAILOR RESISTOR VALUE NOMINAL
10. TAB IS PIN #1 ON ALL MC1550'S
11. TAB IS PIN #10 ON 715



NOTED

3BX102K

RIE #1250-003

30 BELDSOD WIRE

Fig. D-5 Schematic Diagram of the 60-MHz IF Amplifier

2

3. Mode-switching decision circuit

4. Tracking-error signal-processing circuit

A schematic of the signal processing circuit board appears in Fig. D-6. Reference 6 provides detailed design and analysis of the above circuitry.

SYSTEM TIMING

Operation of the timing sequence begins when the IEE is commanded to operate, and provides a negative going 20-μs pretrigger (at the pulse repetition frequency) to the timing circuit. Toggle functions, which are synchronous with the IEE PRF, drive the diode multiplexing switches located in the stripline assembly.

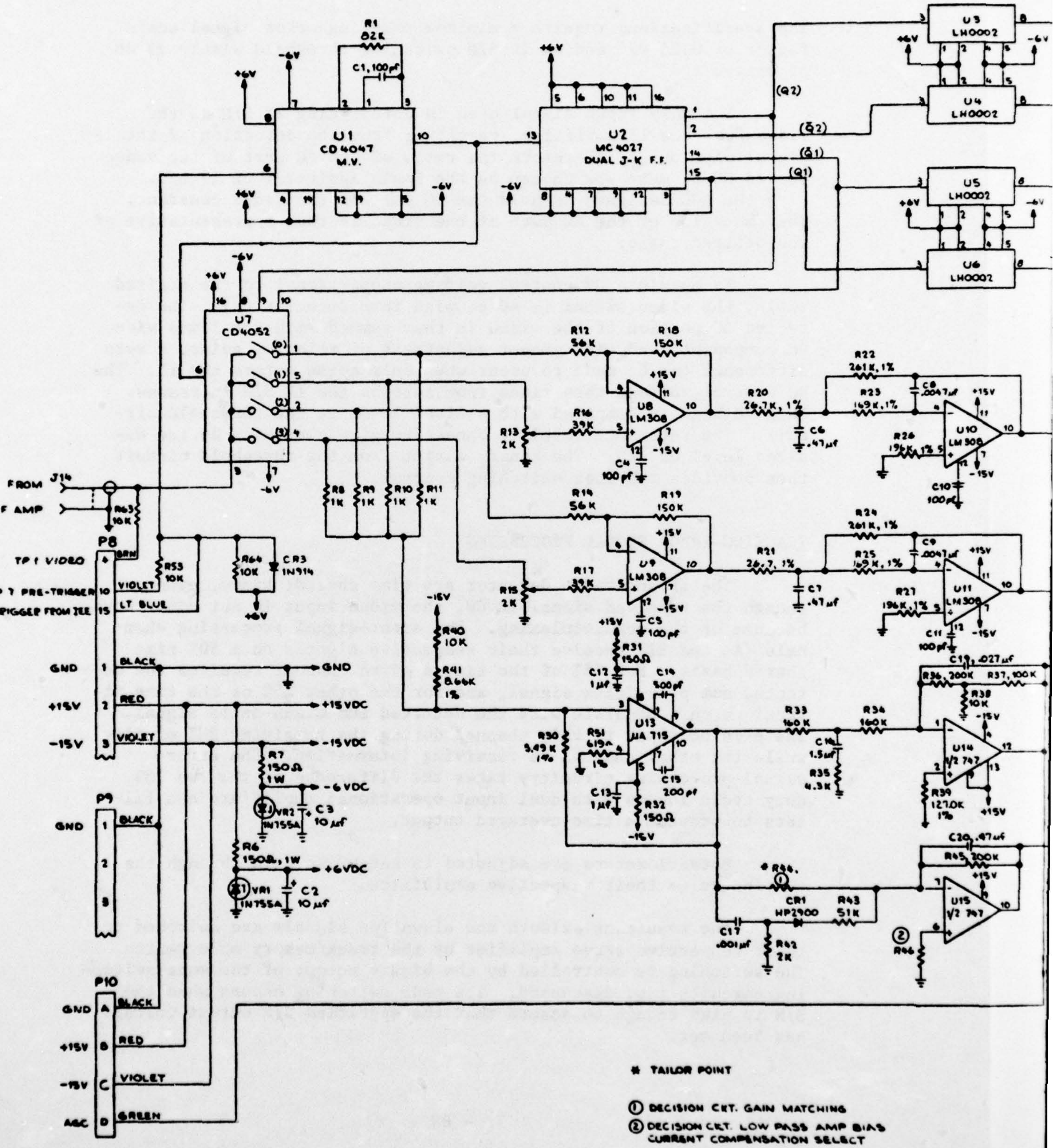
Since the delta (Δ) error signals have been multiplexed and combined into a single channel, they must now be demultiplexed in order to provide the separate Az and El error signals and to recover the tracking error sense. This function is provided by a demultiplexer operating in synchronism with the PRF through two binary control inputs. The 20-μs pulse inhibits operation of the demultiplexer to allow for decay of any transmit pulse feedthrough. The timing sequence is shown in Fig. 5).

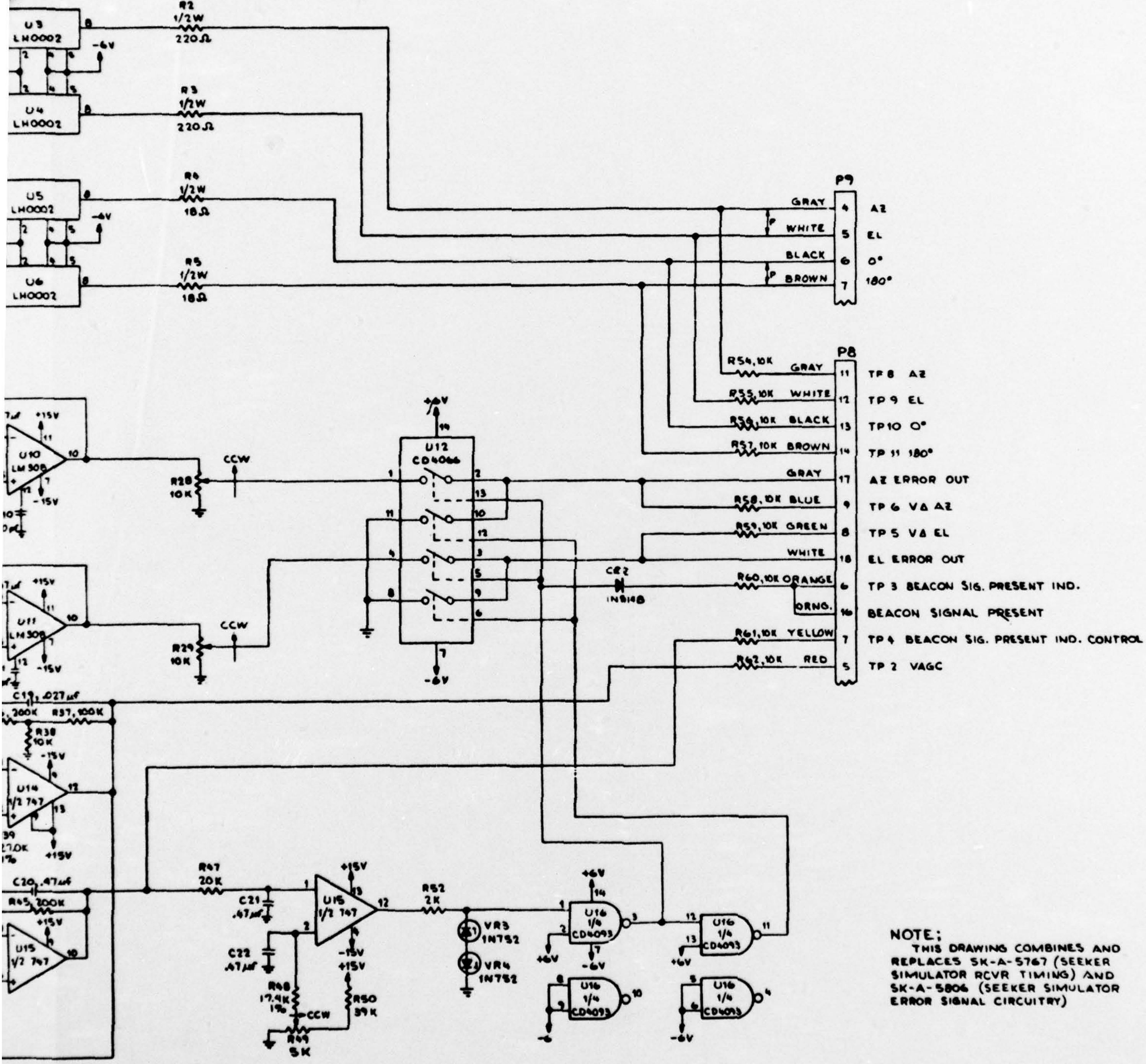
AGC

For the angle information to be useful it must be normalized through AGC action in the IF amplifier. The task of the AGC is to keep the short-time average video level constant in the presence of very large, slow changes and of large, moderately fast changes in the IF input signal. For greater efficiency in filtering off the multiplexing harmonics, the filtering for AGC was chosen as second order. The second order high-pass closed-loop response was obtained by feedback filtering implemented in the operational amplifier configuration U-14 (Fig. D-6) using a lead-lag X first-order low-pass type transfer. U13 proceeds the lead-lag-lag circuit and provides a portion of the necessary gain.

MODE SWITCHING

The mode-switching decision circuit detects when the IF signal-to-noise ratio is high enough for satisfactory tracking.


U1 CD4047 M.V.
U2 MC4027 DUAL J-K F.F.
U3 LH0002
U4 LH0002
U5 LH0002
U6 LH0002
U7 CD4052
U8 LM308
U9 LM308
U10 LM308
U11 LM308
U13 UA 715
U14 1/2 747
U15 1/2 747
FROM J14 IF AMP
TP 1 VIDEO
TP 7 PRE-TRIGGER
PRE-TRIGGER FROM ZEE
GND
+15V
-15V
AGC
P8
P9
P10
BLACK
RED
VIOLET
GREEN
LT BLUE
BRN
+15VDC
-15VDC
-6VDC
+6VDC
CR1 HP2900
CR3 1N914
VR1 1N755A
VR2 1N755A
* TAILOR POINT
① DECISION CKT. GAIN MATCHING
② DECISION CKT. LOW PASS AMP BIAS CURRENT COMPENSATION SELECT



NOTE;
THIS DRAWING COMBINES AND REPLACES SK-A-5767 (SEEKER SIMULATOR RCVR TIMING) AND SK-A-5806 (SEEKER SIMULATOR ERROR SIGNAL CIRCUITRY)

Fig. D-6 Schematic Diagram of the RF Receiver

The specifications require a minimum tracking error signal scale factor of 0.25 V/° and an IF S/N switching threshold within ±3 dB of unity.

The only input signal used in determining IF S/N is the video from the IF amplifier, resulting from the detection of the IF signal plus noise; therefore the ratio of the AC part of the video to its DC or mean was chosen as the basic indicator of IF S/N. With the AGC designed to hold the DC part of the video constant, the rms value of the AC part of the video is then representative of the desired ratio.

To obtain a DC control voltage proportional to the desired ratio, the video signal is AC coupled into detector CR1. The detected AC portion of the video is then summed with the fixed video DC component, and with proper adjustment of relative gains, a zero difference can be made to occur when only noise enters the IF. The DC control voltage then rises from zero as the IF S/N increases. This voltage is compared with a fixed level at the threshold circuit. The reference level is chosen to give switching at the desired level of S/N. The binary output from the threshold circuit then provides the mode switching control.

TRACKING-ERROR SIGNAL PROCESSING

The IF and video detector are time shared; hence, even though the received signal is CW, the video input is not continuous because of the demultiplexing. The error-signal processing channels (Az and El) receive their respective signals on a 50% time shared basis. For 25% of the time a given channel receives the detected sum-plus-delta signal, and for the other 25% of the time it receives on a separate wire the detected sum-minus-delta signal. There is no input to this channel during the remaining 50% of time while the other channel is receiving information. The error-signal-processing circuitry takes the difference of the two 25% duty cycle inputs with dual input operational amplifiers and filters to provide a time-averaged output.

Potentiometers are adjusted to match the gain through the two inputs to their respective amplifiers.

The resultant azimuth and elevation signals are switched to their respective servo amplifier by the track/memory mode switch. The switching is controlled by the binary output of the mode-switching circuits just discussed. The mode switching occurs when the S/N is high enough to assure that the specified S/N output voltage has been met.

Appendix E

GIMBAL SERVO SUBASSEMBLY DESIGN (Ref. 5)

The servo amplifiers receive the error signals from the signal processing circuits and through the torque motors, and feedback potentiometers control the antenna pointing angle via a modified two-bar linkage and gimbal system. The system operating mode is determined by the command-input and signal-present signals (generated in the mode switching circuit of the receiver). There are two command operating modes: cage and uncage (track). These two command signals from the aircraft control demultiplexer are used in flight to select the system operating mode. While the prelaunch signal is present the system is held in the caged mode, assuring that the system will always be in the caged mode when the aircraft is launched. The antenna pointing angle is maintained relative to the aircraft. This angle is adjustable in azimuth and elevation and is normally set to 0° azimuth and 1.25° down elevation to compensate for aircraft flight attitude. In normal operation the aircraft is maneuvered with the system in the caged mode, while the IEE will radiate until there is a "beacon-signal-present" indication. The track operating mode is then initiated by issuing an uncage command. In the track mode the servo amplifier responds to the error signals and positions the antenna to illuminate the ASMD missile launch site. Roll compensation is also applied to assist the tracking loop when aircraft maneuvers involving turn commands are executed.

If the received beacon signal fades while the system is in track mode, the servo amplifier will hold the antenna in the last position prior to signal loss, i.e., switch to the memory mode. The servo amplifier will still react to compensation for pitch and roll while in the memory mode.

A block diagram of the overall antenna position-servomechanism system is shown in Fig. E-1. The elevation channel and azimuth channel are identical, but only the azimuth channel is described in detail.

CAGE MODE

In the cage mode, the track loop is opened by a track-cage discrete signal telemetered up from the ground station. A voltage output from the "cage set" potentiometer determines the antenna position. The signal from the cage-set potentiometer is switched

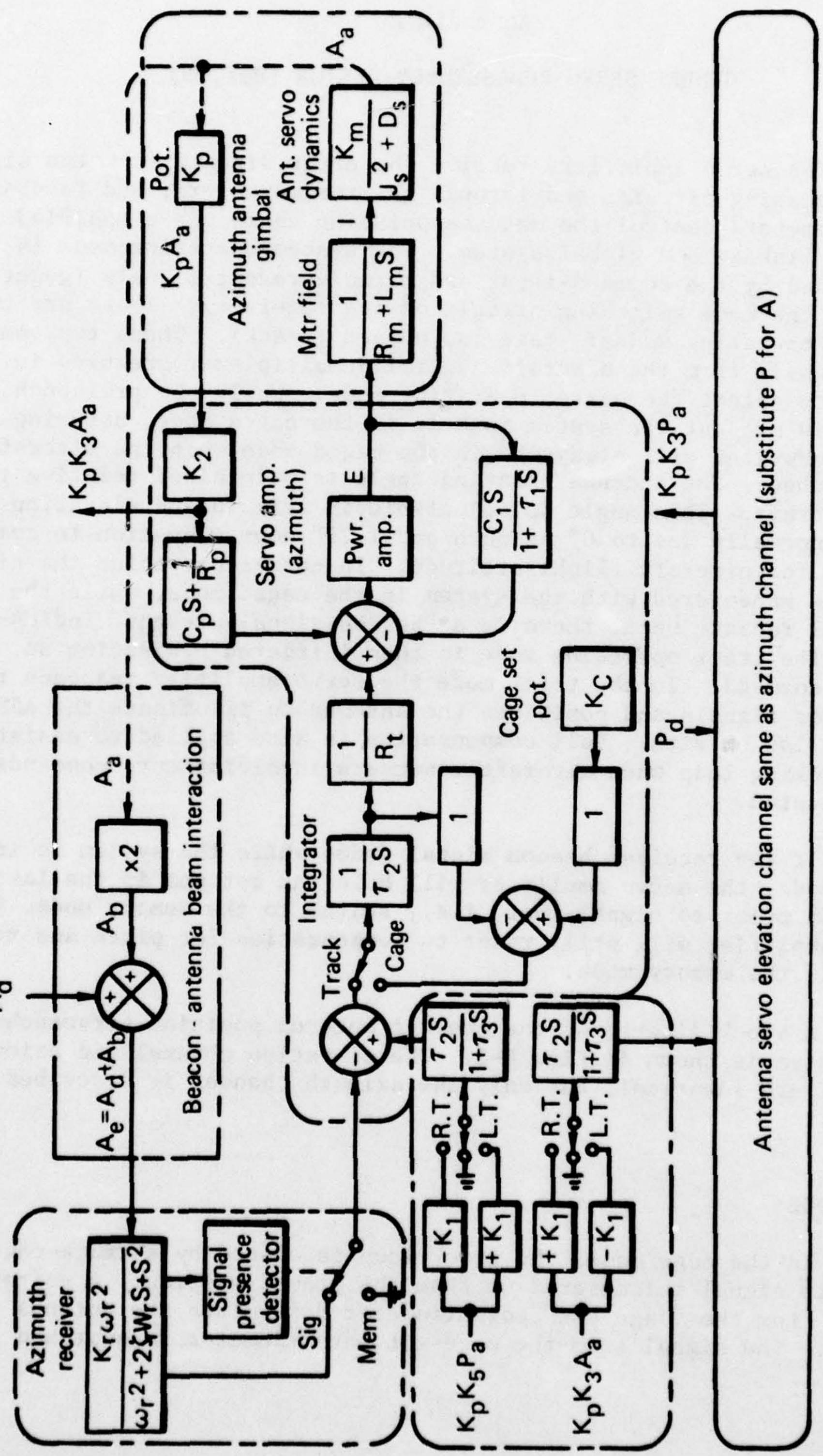


Fig. E-1 Block Diagram of the Antenna Servomechanism

into the integrator along with integrator feedback, changing the integrator into a low-pass amplifier that smooths the transition from track to cage and vice versa. The antenna position is measured by the potentiometer whose voltage is scaled by the input amplifier. In steady-state operation the current through the servo input resistor is balanced by the current through the antenna feedback resistor. A parallel feedback capacitor is used to generate an anticipation current while the antenna is moving, to provide a deceleration signal to the power amplifier, so the antenna will be positioned with minimum overshoot.

TRACK MODE

When the servo system is in the track mode, the track loop is closed. The error signal from the receiver is fed to an integrator, which ensures that the antenna will move until the pointing-angle error to the beacon is zero. Another purpose of the integrator is that if the signal to the receiver fades while tracking, the integrator will hold the angle between the antenna-beam axis and the drone axis at the last value until the signal again has sufficient strength to take over.

In addition to the error signal from the receiver, roll-compensation signals are fed into the integrator. Turn maneuvers are conducted by an exponential roll angle of 30° to the right or left with a time constant of 0.7 second. When the drone goes into a roll, the antenna azimuth and pitch angles must be kept constant in earth coordinates. Since the turn maneuver is repeatable, it is possible to insert the coordinate transform signals directly into the servo mechanism whenever a turn command is initiated.

MEMORY MODE

Whenever the received beacon signal is too weak to provide satisfactory tracking operation, the input to the integrator is grounded, preventing receiver noise from activating the servo system and causing a random wander of the antenna. When the integrator input is grounded, the output remains at the last value except for integrator bias drift. The latter is < 0.1 V/s. With an output scale factor of 1°/V this is equivalent to 0.1°/s. The roll compensation is still active, however, and the antenna responds to the turn maneuvers.

Appendix F

CW BEACON DESIGN

The ground-based CW beacon (Fig. 3 in main text) was designed as the signal source for a target tracking simulator. The unit comprises a unitized assembly having a power supply, SSLO Gunn-effect oscillator, and antenna.

POWER SUPPLY

The power supply is a purchased Power/Mate module, type UNI-30D with the following characteristics.

Output voltage	11 VDC, 5 A (adjustable ±1 V)
Input voltage	105-125 VAC; 50 to 420 Hz; single phase
Line regulation	±0.05%
Load regulation	±0.05%
Polarity	Input/*output* isolated
Ripple	2 mV (rms) maximum
Temperature range	-55°C to +100°C
Short-circuit protected	

SSLO GUNN-EFFECT OSCILLATOR

The CW power source is a purchased Varian VSX-9001, Gunn-effect oscillator with the following specifications.

Frequency	10.0 GHz
Mechanical tuning range	±100 MHz
Power output	1 W (min)
Stability	±5 MHz (max)
Heat-sink range	+5°C to +60°C
Output connector	Mates with VG-39V WG
Input power	+10 to +12 VDC at 3.5 A (max)

To ensure proper frequency for tracking simulator lock-on, final tuning of the SSLO is performed after a minimum of 30 minutes warmup and approximately 30 minutes prior to drone target launch.

BEACON ANTENNA

The beacon antenna is a horizontally polarized I band horn (Fig. 3). The horn is positioned in the CW beacon assembly at a 6° up angle which places the 3-dB point of the antenna elevation pattern on the horizon (assuming the unit to be on a level plane). A leveling bubble and adjustable feet have been provided to ensure that this requirement can be met. Shipboard operations require the beacon to be placed on a stabilized platform for stabilizing the antenna beam to ensure maximum acquisition by the target tracking simulator.

Following are the operating characteristics of the beacon antenna.

Frequency	10.0 GHz
Antenna	
3-dB bandwidth	
Azimuth	30° ± 3°
Elevation	$10^{\circ}\,{}^{+2^{\circ}}_{-0^{\circ}}$
Gain	20 dB

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